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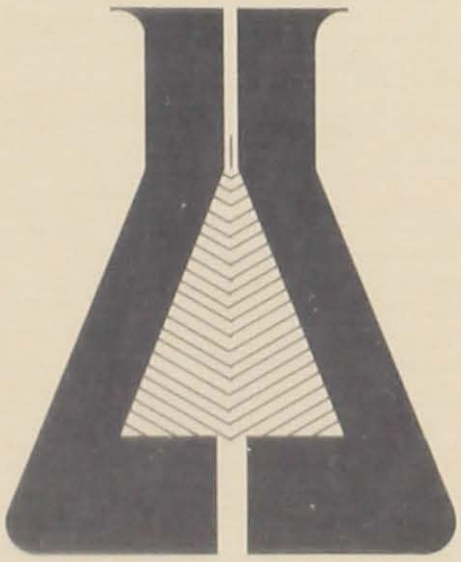
FOREST SERVICE
RESEARCH ACCOMPLISHMENTS
1975



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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Washington, D. C. 20250

1380(4000)

Mr. Robert W. Long
Assistant Secretary
U.S. Department of Agriculture
Washington, D. C. 20250

Dear Secretary Long:

I am pleased to send you the report on Forest Service Research Accomplishments for 1975.

This report presents an overview of Forest Service research achievements and a comprehensive list of publications. It reflects the emphasis of a research program directed at solving the multifaceted problems of managing our Nation's renewable natural resources.

The new technology reported here will be useful to other scientists and to practitioners in Federal, state and private employment. The Forest Service is strengthening its efforts to assure that this technology is quickly transferred to and utilized by those who need it.

Sincerely,

John R. McGuire

JOHN R. McGUIRE
Chief

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U.S. DEPARTMENT OF AGRICULTURE

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FOREWORD

Forest Service research plans are coordinated through the Assistant Secretary for Conservation, Research, and Education with research in other USDA agencies, as well as that conducted under the Hatch Act at land grant institutions, and under the McIntire-Stennis Act at schools of forestry.

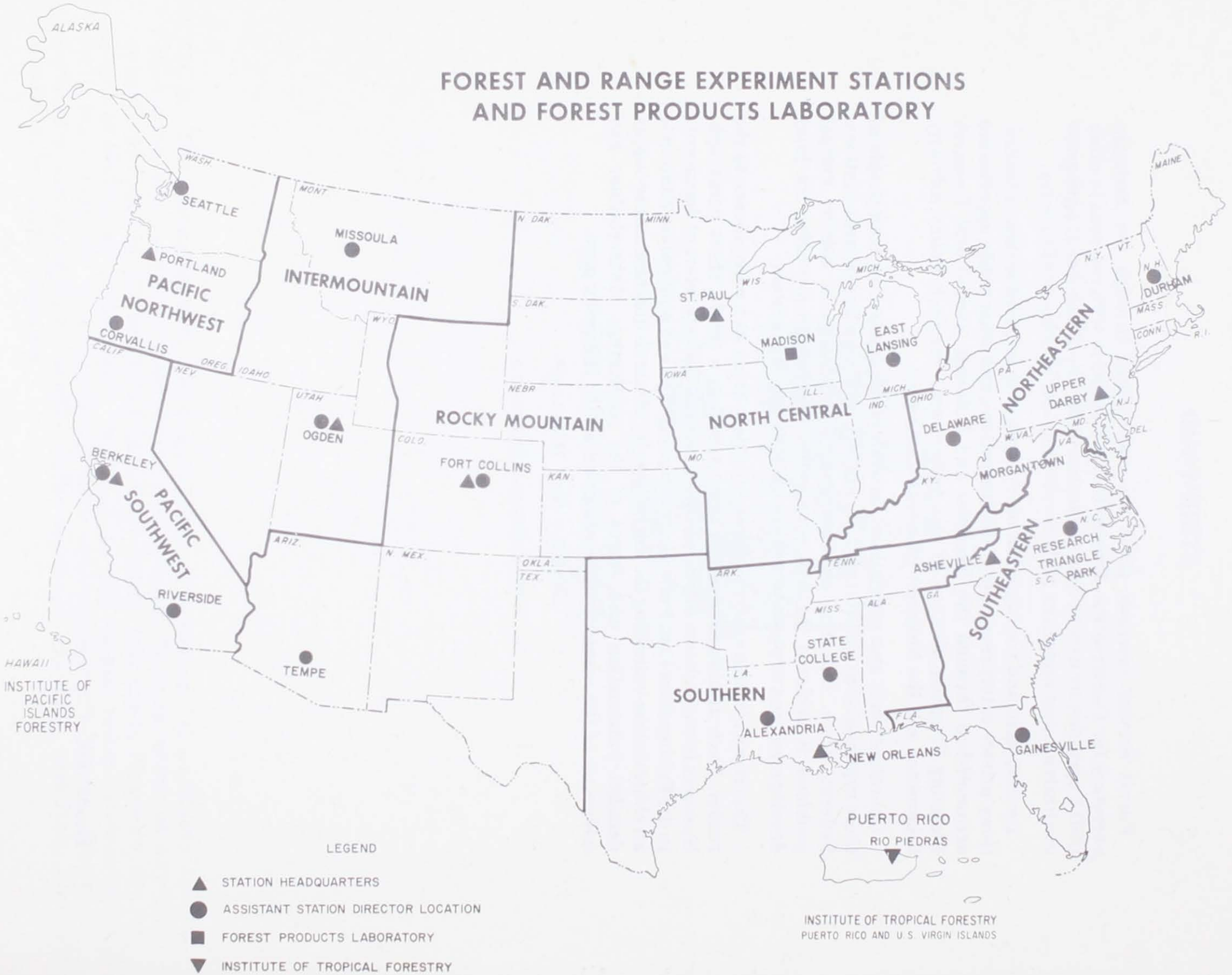
Development and coordination of research with other educational institutions, private enterprises, nonprofit institutions, and other public agencies are accomplished through the Regional and National Agricultural Research Planning Program directed by the Agricultural Research Policy Advisory Committee and the National Planning Committee.

Coordination is also maintained through direct contact between people of these organizations and those of the Forest and Range Experiment Stations. Federal, State, industry, and university cooperation in solving mutual problems is achieved through cooperative agreements providing for joint development and support of the research by the cooperators.

This report is arranged by research subject areas as a convenience to the reader. Each accomplishment is summarized in a single, short paragraph. Numbers in parentheses following the paragraph indicate relevant documents in the Publications List. Following each paragraph and publication citation is an abbreviation indicating the Forest Service research unit best able to supply detailed information and copies of the publication. Abbreviations and addresses of the research units are given on the following page.

Issued 1976

FOREST AND RANGE EXPERIMENT STATIONS AND FOREST PRODUCTS LABORATORY



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Portland, Oregon 97208

PSW
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Pacific Southwest Forest and Range Experiment Station
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INT
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Intermountain Forest and Range Experiment Station
507 25th Street
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RM
Director
Rocky Mountain Forest and Range Experiment Station
240 West Prospect Street
Fort Collins, Colorado 80521

NC
Director
North Central Forest Experiment Station
Folwell Avenue
St. Paul, Minnesota 55101

NE
Director
Northeastern Forest Experiment Station
6816 Market Street
Upper Darby, Pennsylvania 19082

SE
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Southeastern Forest Experiment Station
Post Office Building, P. O. Box 2570
Asheville, North Carolina 28802

SO
Director
Southern Forest Experiment Station
T-10210 Federal Building
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New Orleans, Louisiana 70113

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Director
Forest Products Laboratory
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Madison, Wisconsin 53705

ITF
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Institute of Tropical Forestry
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Washington, D.C. 20250

RESEARCH ACCOMPLISHMENTS — 1975

CONTENTS

		Page	Paragraph Number
I.	IMPROVING ENVIRONMENTAL QUALITY, PRODUCTIVITY, AND USEFULNESS		
	A. Reducing Pollution	1	
	1. Controlling soil erosion		1–9
	2. Chemicals in the forest environment		10–15
	3. Air pollution		16–21
	4. Recycling wastes—sewage effluent, sludge, and residues		22–25
	B. Improving Wildlife, Range, and Fisheries Habitat	3	
	1. Characteristics and values of plants for food and cover		26–35
	2. Fish habitat resources		36
	3. Wildlife habitat resources		37–50
	4. Rangeland management		51–59
	C. Improving Social and Amenity Values	5	
	1. Environmental amenities—landscapes and open space		60–63
	2. Environmental amenities—wilderness		64–72
	3. Managing recreation opportunities		73–90
	D. Environmental Tree Culture	8	91–96
	E. Ecology and Classification of Natural Vegetation	8	97–108
	F. Improving Environmental Quality Through Fire Management	9	
	1. Fire prevention, hazard reduction, and prescribed burning		109–131
	2. Fire management methods and systems		132–153
	3. Forest fire science		154–161
	G. Improving Insect and Disease Control	14	
	1. Detection and evaluation		162–173
	2. Biology and understanding		174–290
	3. Pest control techniques		291–321
	4. Pest management strategies		322–323
	H. Improving the Water Resource	26	
	1. Water quality		324–330
	2. Water yield and timing		331–345
	3. Managing, rehabilitating, and improving watersheds		346–381
	I. Forest Resources Evaluation	30	
	1. Resource inventories		382–390
	2. Utilization and production		391–395
	3. Inventory and analysis techniques		396–398
	J. Bettering Silvicultural Systems	32	
	1. Natural regeneration		399–409
	2. Silvicultural methods		410–427
	3. Ecological relationships		428–437
	K. Economics of Forest Management	35	
	1. Methods of financial evaluation and planning		438–440
	2. Timber growing economics		441–447
	3. Multiple-use economics		448–453
	4. Impacts on forest industry and regional economics		454–456
	L. Weather Modification and Weather Effects	36	457–469
	M. Reclamation of Mined Lands	37	470–484
II.	IMPROVING UTILIZATION AND EXTENDING WOOD SUPPLIES		
	A. Intensive Culture Methods	39	
	1. Site evaluation and soil improvement		485–508
	2. Artificial regeneration		509–553
	3. Stand improvement		554–565
	4. Animal damage		566–572
	5. Growth requirements		573–597
	6. Growth and yield		598–605
	7. Forest measurements		606–617
	8. Management planning		618–625

	Page	Paragraph Number
9. Maple syrup production		626–627
10. Naval stores		628–631
B. Breeding Improved Trees	50	
1. Inherent variation		632–651
2. Insect-disease resistance		652–657
3. Tree breeding methodology		658–675
C. Improving Uses and Protection of Wood	54	
1. Utilization potential and processing of wood		676–717
2. Wood chemistry and fiber products		718–737
3. Wood engineering		738–753
4. Biological degradation		754–757
5. Prevention and control of wood-destroying organisms		758–763
D. Marketing Under-used Species and Residues	60	764–765
E. Supply, Demand, and Price Analysis	60	766–771
F. Improved Marketing Systems	61	772–779
Publication List and Indexes	viii	

PUBLICATION LIST AND INDEXES

	Page	*Publication Number*
FOREST ENVIRONMENT RESEARCH		
Watershed Management Research	63	
Controlling soil erosion		1–12
Chemicals in the forest environment		13–22
Recycling wastes—sewage effluent, sludge and residues		23–26
Reclamation of mined lands		27–44
Managing, rehabilitating, and improving watersheds		45–145
Water quality		146–154
Wildlife, Range, and Fisheries Habitat Research	69	
Characteristics and values of plants for food or cover		155–195
Fish habitat management		196–201
Wildlife management		202–243
Livestock management on rangelands		244–268
Forest Recreation Research	74	
Environmental amenities—landscapes and open space		269–272
Environmental amenities—wilderness		273–283
Managing recreational opportunities		284–314
FOREST INSECT AND DISEASE RESEARCH		
Forest Insect Research	77	
Detection and evaluation		315–320
Biology and understanding		321–395
Pest control techniques		396–427
Prevention and control of wood-destroying organisms		428–433
Forest Disease Research	81	
Detection and evaluation		434–444
Biology and understanding		445–520
Pest control techniques		521–527
Prevention and control of wood-destroying organisms		528–533
Air pollution		534–540
FOREST FIRE AND ATMOSPHERIC SCIENCES RESEARCH		
Fire prevention, hazard reduction, and prescribed burning	87	541–576
Fire management methods and systems	88	577–600
Forest fire science	89	601–613
Ecological relationships	89	614–616
Weather modification and weather effects	90	617–631
TIMBER MANAGEMENT RESEARCH		
Biological Relationships	91	
Forest ecology		632–654
Site evaluation and soil improvement		655–683
Growth requirements		684–721
Animal damage		722–729
Distribution and classification of trees		730–739
Environmental tree culture		740–746
Silviculture	95	
Natural regeneration		747–758
Silvicultural methods		759–780
Stand improvement		781–796
Artificial regeneration		797–851
Growth and yield		852–862
Management and Mensuration	99	
Forest measurements		863–877
Management planning		878–889
Genetics and Tree Improvement	100	
Inherent variation		890–918
Insect-disease resistance		919–925

	Page	Publication Number
Tree breeding methodology		926–946
Special Products	103	
Maple syrup production		947–949
Naval stores		950–955
FOREST ECONOMICS AND MARKETING RESEARCH		
Forest Resource Evaluation	105	
Resource inventories		956–986
Utilization and production		987–1008
Inventory and analysis techniques		1009–1024
Forest Economics Research	107	
Methods of financial evaluation and planning		1025–1029
Timber growing economics		1030–1043
Multiple-use economics		1044–1053
Impacts on forest industry and regional economics		1054–1060
Forest Products Marketing Research	109	
Marketing under-used species and residues		1061–1071
Supply, demand, and price analysis		1072–1088
Improved marketing systems		1089–1119
FOREST PRODUCTS AND ENGINEERING RESEARCH		
Forest Engineering Research	113	
Improving engineering systems		1120–1156
Forest Products Utilization Research	114	
Utilization potential and processing of wood		1157–1252
Wood chemistry and fiber products		1253–1297
Wood engineering		1298–1334
Author Index	121	
Taxonomic Index	127	
Keyword Index	133	

IMPROVING ENVIRONMENTAL QUALITY, PRODUCTIVITY, AND USEFULNESS

Reducing Pollution

Controlling soil erosion

1. Surface erosion from road construction, mining, and the like, may create serious impacts on fish habitat and other watershed values. A model for predicting surface erosion in the Idaho Batholith indicates that surface erosion is highest immediately after disturbance and decreases rapidly over time. Increased stoniness of the ground surface (erosion pavement) appears to be the dominant factor causing the trend. Mulching, netting, and transplanting can reduce soil losses during the period before seeded vegetation becomes established. —INT(10).

2. Ponderosa pine is well suited for stabilization of road fills in the Idaho Batholith. Ninety-seven percent of the trees planted survived. Growth was increased 95 percent by fertilization. Erosion was reduced 32 to 95 percent, depending on whether straw mulch and netting were used in combination with tree planting. —INT(11).

3. Most eroded areas of the southern Coastal Plain can be successfully stabilized by bar-planting loblolly pine, but some sites defy repeated efforts. Statistical analysis of the chemical and physical characteristics of soil were used to detect hard-to-plant areas. Bulk density was the most important variable as it alone correctly predicted the success or failure for 78 percent of the sites. Where densities exceed 1.45 g/cm^3, alternate planting methods are required. —SO(7).

4. Lovegrass planted and fertilized to quickly protect a site may overwhelm pine seedlings and thus prevent permanent control of erosion. This problem was solved on sandy soils in northern Mississippi by delaying application of two-thirds of the required fertilizer until late July. The delay boosted pine survival from 33 percent to 73 percent—a rate near that of pines grown free of grass competition. The results demonstrate that combined plantings are feasible for both rapid and long-term site protection if competition between species is controlled. —SO(6).

5. Major highway construction is under stringent regulation in subarctic Alaska, but pioneer type access roads have been neglected. These smaller roads are often erosion hazards and may contribute to fire and insect problems. Guidelines for development of roads in the subarctic have been designed for road builders with limited engineering and planning staffs. They are based on Federal and State environmental regulations for the conterminous United States modified by local experience in subarctic conditions. —PNW(106).

6. Mass soil movements reduce site productivity by removing soil material and lowering nutrient capital available for plant growth, and they introduce significant quantities of sediment into forest streams. Natural mass movements on forested slopes in the western United States can be divided into two major groups, (1) debris movement and (2) soil mantle movement. Steep slopes, high soil moisture, and periods of abnormally high rainfall are commonly associated with movement. Logging operations can be major contributors to this process. Future land management operations can influence or be influenced by soil mass movements. —PNW(131).

7. Landsliding in steep glaciated terrain of southeast Alaska is a serious problem for forest land managers. Soil mass movements are the dominant erosion process on the steep forested slopes. Effective management of such terrain consists of identification and avoidance of the most unstable areas and careful control of timber harvesting operations in questionable zones. —PNW(132).

8. One of the more visible and controversial environmental impacts associated with timber harvesting in subalpine coniferous forests is road building. A preliminary model has been developed for predicting an index of onsite erosion and downstream sediment yield. By describing the disturbed area in terms of watershed slope and engineering design, the land manager is provided some flexibility in evaluating the impacts of various road systems in the central Rocky Mountains. —RM(9).

9. Field survey and design procedures conventionally employed for control of gullies on forests and rangelands require relatively high expenditures of time and money. Design of gully control with check dams has been computerized and made operational for field use. The computer program requires a minimum of data to generate designs and to furnish critical information concerning materials and costs for alternative designs. This procedure can facilitate inventory of needs for gully control and the selection of treatments where control is necessary. —RM(8).

Chemicals in the forest environment

10. TCDD, a contaminant of commercially produced 2,4,5-T, may enter forest streams with the herbicide during aerial application on forest land. Exposure of guppies to 0.1, 1.0, and 10.0 ppb TCDD for 120 hours caused complete mortality in the next 32, 21, and 30 days, respectively. Duration of survival was significantly and positively correlated with body length. Concentrations of TCDD used in the tests were significantly greater than expected to occur in forest streams after aerial application of 2,4,5-T. —PNW(22).

11. Cacodylic acid and MSMA (arsenical silvicides) are used in precommercial thinning of Pacific Northwest forests, but their impact on soil microorganisms is not known. Both chemicals inhibited the growth of four bacteria in liquid culture at 1000 ppm but not at 100 ppm. Concentrations of less than 10 ppm arsenic had no sigificant effect on decomposition of organic matter. Neither chemical will seriously affect forest microbial populations, their decomposition of organic matter, or other functions important in the maintenance of soil fertility. —PNW(13).

12. There is concern that the use of endrin on forest tree seeds may introduce significant quanitites of the chemical to the aquatic environment. Following aerial seeding of two western Oregon watersheds with treated Douglas-fir seed, detectable residues of endrin were found in a steep gradient

stream for a period of less than 5 hours and in a slower flowing stream for 11 days. Maximum concentrations were well below 96-hour median tolerance limits for important fish species. —PNW(17).

13. An understanding of the behavior of pesticides in plants is necessary to accurately evaluate the consequences of pesticide usage in the forest. Chemical and physical properties of a pesticide and interacting environmental factors determine the movement, persistence, and fate of pesticides in plants. The behavior of a pesticide determines its field effectiveness and its residue characteristics. —PNW(19).

14. Salt (NaCl) used to deice highways has injured roadside trees in the Lake Tahoe Basin of California. In 1 year, an estimated 3,000 trees were damaged or killed on 321 sites. Symptoms and concentration of salt in the needles of exposed trees were determined and described. Results will help the State Division of Highways develop environmental impact statements and indicate the need for additional studies in the area. —PSW(440).

15. Although mirex has been the standard insecticide for control of the imported fire ant in the southern United States since 1963, relatively little is known about the interaction of this insecticde with soil microorganisms. Field and laboratory studies show that mirex is not degraded by and appears to be innocuous to soil microorganisms. Mirex remains in unconsumed bait but becomes slowly incorporated into the soil as the bait decomposes. It does not leach into ground water, but it is probably washed into streams and lakes by surface runoff. This information will provide some of the basis for evaluating current and future use of this insecticide. —SE(15).

Air pollution

16. Injury of ponderosa and sugar pine caused by air pollution is significant in southern California, but guidelines for distinguishing this damage from other common foliage problems have been lacking. Changes in needles of ponderosa pine caused by ozone (O_3) and sulfur dioxide (SO_2) singly and in combination were delineated microscopically and contrasted with winter fleck injuries. The ability to identify air pollution damage in the western United States will permit scientists and researchers to develop better management and control recommendations for minimizing the effects of air pollution. —PSW(536,539).

17. As urbanization and industrialization intensify, harmful gaseous and particulate emissions will adversely affect forest, nursery, and ornamental plantings. Nature, extent, and severity of ambient pollutants on coniferous and deciduous forests and seedlings have been described. This information will give nursery managers and foresters in the United States a better understanding of the causes and effects of air pollution, and enable them to develop improved management plans to minimize future losses. —NE(534,535).

18. To accurately evaluate air pollution resistance in trees requires long-term exposure to chronic low levels of pollutants. An attempt was made to develop a technique for shortening the evaluation time by correlating the response of plants to high and low levels of ozone. Fumigation of hybrid poplar clones with 15 pphm (O_3) for 6 weeks caused a 50 percent growth loss and injured 75 percent of the foliage, but exposure of the same clones to 100 pphm for 2, 4, or 8 hours did not suppress growth though 70 percent of the leaves were injured. Lack of correlation between these treatments means nurserymen, tree breeders, and geneticists cannot use short-term, high-concentration tests to predict pollution tolerance in trees. —NE(538).

19. If toxicants were not removed from the atmosphere, air pollution would rapidly increase. Biological systems, e.g., forests, undoubtedly remove some, but which ones and how much are not known. Eastern American hardwood seedlings rapidly absorbed sulfur dioxide (SO_2) and moved this chemical from leaves to roots. Thus, plant species with long-term SO_2 absorption capacity may serve as sinks in locations where chronic pollution occurs. If confirmed, this information will be valuable to land managers throughout the country who will need to select species for future reforestation. —NE(537).

20. Air pollution damage to shade trees is widespread and of increasing economic and biological importance. Effort is currently being made to produce a tree with greater adaptability to eastern and midwestern urban environments. Tests with red maple indicate that seedling response to ozone exposure is genetically controlled. Through breeding and selection, urban foresters and geneticists may be able to develop red maple with increased ozone tolerance. —NE(540).

21. The sensitivity of trees to air pollution can be affected by many factors, such as nutrient levels in the soil. A greenhouse study in North Carolina showed that nitrogen fertilization significantly increased needle tip necrosis when potted propagules of a clone of eastern white pine were exposed to ambient air pollution. Conversely, phosphorus fertilization significantly reduced average needle injury and the number of affected needles over the entire tree. Further studies are obviously needed, but these results suggest that pollution damage might possibly be diminished by selected fertilization. —SE(662).

Recycling wastes--sewage effluent, sludge, and residues

22. Forests are potential sites for treatment and disposal of sewage wastes, but overirrigation with sewage effluent could result in excess moisture and nutrients. After effluent irrigation, a 20-year old stand of red pine and young deciduous and conifer seedlings on a sandy site in southern Michigan showed improved growth and survival of most species. Boron toxicity symptoms were indicated in the red pine needles. One to 2-inch irrigation treatments at this site appear to be environmentally acceptable. —NC(25).

23. Treatment and disposal of sewage wastes from forest campgrounds has been a difficult problem for land managers. Wastes from sewage vaults were injected into a sandy soil site on the Hiawatha National Forest in upper Michigan. Tests for bacteria and chemicals indicate on-site soil treatment protected the surrounding soil and water resources. With proper site selection, soil incorporation provides cheap, effective, and safe treatment of sewage from remote campgrounds. —NC(24).

24. Sewage effluents and sludges from municipal and industrial sources provide potential water and nutrient sources for intensive culture of forest crops. Pulp and paper mills may soon be required to use land renovation to meet effluent discharge standards. Intensive-culture forestry offers the only wideland management alternative that gives adequate nutrient uptake to provide long-term renovation of wastewater. Nitrogen enrichment of groundwater may be the controlling factor in such practices. —NC(26).

25. Management of forest residues may impact soil microbes important in the maintenance of soil fertility. Interactions between soil microbes and forest residues are controlled by six environmental factors which are drastically affected by burning. Microbial decomposition of forest residues recycles nitrogen and can improve soil physical properties. Microbial activity can be enhanced by reducing particle size of

residues, by providing good contact between residue fragments and soil, and by adding nitrogen to the site. —PNW(23).

Improving Wildlife, Range, and Fisheries Habitat

Characteristics and values of plants for food and cover

26. Bitterbrush is an important livestock and wildlife food in central Oregon. However, little is known about the impact of logging and slash disposal on bitterbrush. On a forested site, logging destroyed 71.5 percent of the bitterbrush crown area. Forage production recovered in 5 years after logging and continued to increase for 12-15 years. Disposal of slash was the primary cause of soil disturbance and reduction in shrub cover. Production of forage for livestock, deer and elk improved for 15 years. These results were used in establishing guidelines for coordinated management of timber and wildlife habitat. —PNW(161).

27. Information about seed is essential for producing shrubs to improve habitat for wildlife, furnish forage for livestock and protect soil from erosion by wind and water. Successful restoration of shrublands is dependent upon a basic understanding of the biology of native plants. Biological information about many shrubs on forest and rangelands has been summarized. Flowering and fruiting characteristics, seed collection, storage practices, and germination techniques are described. Land managers now have a current summary of the state of knowledge about shrub seeds. —PNW(186,188,190).

28. Short-hair sedge vegetation in the high Sierra Nevada of California is susceptible to abuse, and its rate of recovery is slow. The condition of vegetation was compared at several locations. Overuse was destroying short-hair sedge vegetation, leaving patches of bare ground. The rate of recovery was extremely slow, requiring 70 years or more. These sensitive areas will require special attention to insure their continued productivity. —PSW(185).

29. In the eastern megalopolis, changes in land use are very rapid. Land use planners at town, county, and State levels need statistics, maps, and classification procedures to document changes in land use. To meet these needs in Massachusetts, a system for classifying land from aerial photographs and producing maps of areas as small as 3 acres was developed. Changes in vegetation and land use between 1951 and 1971 have been documented using this method. This system is an integral part of the effort to prepare a catalog of maps of Massachusetts useful to resource managers and planners in the future. —NE(167,168,169,170,171,173).

30. Land managers in the South need a better understanding of the geographic range of bluestem, an important forage plant for livestock and wildlife. Researchers found that separation of varieties of bluestem below the species level is impractical in management of southern range. Range management practices developed in one location are expected to produce similar responses in bluestem elsewhere. —SO(164,165).

31. Trees, shrubs, and woody vines constitute the major source of food and cover for wildlife in southern forests. One must be able to identify these important plants in order to evaluate habitat. The task is difficult, especially during the winter when the more recognizable plant features such as leaves, flowers, and fruits are often absent. A new publication describes and illustrates some key identification features of 70 species. It stresses the characteristics of stems and buds in winter, since a description of these parts is rarely available in taxonomic references. As an aid in identification, species are grouped according to physical characters such as growth form (vines or shrubs), leaf, stem, and bud arrangement, and leaf persistence. This information will be useful to conservationists and land managers in identifying species for determination of wildlife habitat values. —SO(178).

32. Documenting use of habitat by animals is a most difficult problem. As a result of miniaturization of electronic components, radio transmitters can now be made for small animals such as the Abert squirrel. By radio tracking three squirrels in Arizona, it was found that each squirrel used from two to six nests in home ranges of 10 to 85 acres. Wildlife managers can use these data to develop criteria for evaluating habitat and to determine appropriate management units for Abert squirrel. —RM(179).

33. Ranchers in the Bighorn Mountains of Wyoming are interested in replacing big sagebrush with higher quality range plants. They need methods to control big sagebrush. In 1960 and 1961, big sagebrush (*Artemisia tridentata*) on four cattle ranges was sprayed with 2,4-D to improve livestock forage. By 1971, the canopy cover of big sagebrush was 8-42 percent of the pretreatment levels. Seedling density ranged from 5.7 to 11.3 plants/120 ft^2. Herbage production was below the pretreatment levels with the proportion of graminoids about equal to that prior to spraying. Effects of deferment of grazing for as long as 3 years after spraying could not be detected. Increased herbage production after sagebrush control with 2,4-D was a short lived phenomenon lasting 3-5 years. —RM(192).

34. We need to know how and if low-resolution ERTS imagery can be used for inventory of natural renewable resources. Visual interpretation and machine processing of midsummer ERTS-1 imagery of a central Colorado mountainous area provided 85 percent accuracy for classifying conifer forests, deciduous forests, and grasslands. Classification for kind of forest, i.e., ponderosa pine, lodgepole pine, spruce/fir, Douglas-fir, and aspen, or grassland, i.e., bunchgrass or shortgrass, was not as successful. However, adjusting the apparent spectral signature of the ponderosa pine forest to account for slope differences improved classification by machine processing. ERTS type imagery would be useful for a first level stratification for inventories of renewable resources on a regional basis. —RM(160).

35. Improved grazing systems, based on the growth habits of forage plants, are needed to restore southwestern semidesert ranges to full production. The process of seed production in a perennial grass usually begins toward the latter part of the summer growing season, when microscopic changes occur in the growing point at the upper end of the shoot. At the time it changes from a vegetative to a reproductive condition, the growing point is probably less than 1/200-inch long. From this tiny beginning, the mature inflorescence rapidly develops. When grasses are in the early reproductive stage of development, a single bite by a rodent or a cow can remove not only the developing seed head but also prevent the development of a shoot and its associated leaves. On the other hand, if grasses are allowed to make substantial growth before they are grazed, fewer stems are needed to supply a cow's daily needs. —RM(157).

Fish habitat resources

36. The herbicides 2,4-D and 2,4,5-T are used to control brush in Oregon and Alaska. Toxic contaminants from the herbicides may enter forest streams during spray operations. Researchers at Corvallis, Oreg. have determined levels of tox-

icity for several species of salmon and other aquatic organisms. This information helps resource managers predict the impacts of herbicides on aquatic organisms. —PNW(200,201).

Wildlife habitat resources

37. Winter feeding is increasing the number and diversity of birds in and around suburban and metropolitan areas. In Amherst, Mass., 43 percent of the households queried fed wild birds during the winter months. The average household maintained 1.7 feeders and spent $8.80 annually on bird food. The feeding of wild birds in suburban and metropolitan areas is a $50 million a year industry. Wild bird feeding is important to a local economy and to songbird numbers, in addition to providing enjoyment to the public. —NE(206).

38. How can people and wildlife be brought together in an urban environment to provide maximum human benefit without destroying the wildlife? Wildlife biologists at Amherst proposed a strategy for managing wildlife in urban areas. Basically, wildlife management in cities must shift from pest control of rats, pigeons, and the like, to providing nongame wildlife solely for enjoyment. This analysis will be used to guide future research programs concerned with urban wildlife management. —NE(207,208).

39. Research in West Virginia suggests that songbirds can be concentrated in places where forest visitors can study, watch, and enjoy them. Songbird density and diversity in the Central Appalachians correspond to the kinds and quantity of shrubs in the understory. Requirements for nesting habitats of 31 species of birds have been summarized to guide management of songbirds. Managers in the southern Appalachians now have guidelines for managing habitats to increase forest visitor opportunities to see and enjoy songbirds. —NE(213).

40. DDT was sprayed on Oregon forests at the rate of 0.75 pounds per acre to control the Douglas-fir tussock moth. Researchers evaluated the short term DDT effects on survival of nestling songbirds and found no detrimental short term effects on mountain blue birds or house wrens. Nest boxes were placed in a spray and nonspray area to attract mountain blue birds and house wrens. The number of eggs laid and hatched and survival of nestlings were compared to determine the impacts of DDT. These results provide managers with some quantitative data on short term impacts of DDT on songbirds, but results should not be extrapolated to other species of insectivorous birds or to other habitat types. —PNW(239).

41. This state-of-the-art publication contains 34 separate papers ranging from philsophical aspects, problems with people-wildlife interactions, habitat requirements for urban wildlife, the role of the Federal and State governments in urban wildlife, to suggestions on management of people through education. The proceedings represent the first effort at summarizing the state of knowledge and are useful for planning and management of wildlife in urban environments. —NE(223).

42. To improve the quality of urban environments, many residents invite wildlife into their backyards. As the diversity of wildlife habitat increases, the chance of conflicts between man and wildlife also increases. Researchers in Massachusetts, stressing the need to become familiar with the animals' mode of life, compiled practical ideas and devices to minimize chances of conflicts. Using these suggested practices will help prevent conflicts with raccoons and skunks in your garbage can, squirrels in the attic, and chimney swifts in the chimney. This practical guide is useful for urban residents who share their backyards with wildlife. —NE(238).

43. Hunters and land managers in Florida are concerned about low deer populations in the Central flatwoods. Up to now, the causes have not been known. Recent research found that total numbers of deer in an area, variety of available food, and methods of hunting were not correlated with rate of reproduction. Deer reproduction was limited by low soil fertility resulting in food having a high lignin content and deficient in iron, copper and cobalt. Deer numbers can be increased by using one of several recommended methods to improve forage quality. —SE(216).

44. Clearcutting can adversely affect woodpeckers in southern Appalachian forests. Habitat preferences of four species of woodpeckers were identified and related to regrowth of forests following clearcutting. These data provide guidelines to land managers for maintaining woodpeckers in forest habitats. —SE(204).

45. Management of brood range of turkeys requires knowledge of the habits of free-ranging poults, but poults with hens are extremely difficult to observe in the wild. To overcome this problem, poults were imprinted to wildlife biologists. Human-imprinted turkeys make ideal research animals, whose behavior can be measured and used to define habitat needs. Use of imprinting-to-humans is not limited to precocial and ground dwelling birds. This approach should be useful in many studies of animal behavior and ecology. Information gathered by this method provides managers with the first quantitative information on habitats of turkey poults under near natural conditions. —NE(218).

46. Cutting ponderosa pine forests in Arizona is changing deer and elk habitat. Small, irregular, clearcut patches create diversity and provide large amounts of forage. Deer and elk benefit if there is adequate cover in scattered stands of saplings, poles, and sawtimber adjacent to the openings. Forest managers can improve deer and elk habitat by cutting one-sixth of a well stocked watershed in patches that range from a few to 32 acres. —RM(225).

47. Abert squirrels in Arizona clip twigs of ponderosa pine in winter to feed on the inner bark. The amount of food consumed can be estimated from a table that gives dry weight of the inner bark from dry weight of peeled twigs. A knowledge of the amounts and kinds of food consumed by the Abert squirrel helps ecologists understand one part of the nutrient cycle and energy flow in the ponderosa pine ecosystem. —RM(224).

48. High density of pocket gophers can cause serious damage to mountain rangelands. Therefore, it is necessary to monitor population fluctuations. Research in high mountain grasslands of Colorado shows that large-scale (1:1600) aerial photographs can be used for that purpose. Mounds of soil produced by gophers in late summer are highly correlated to population density. This method provides a more easily determined population density estimate and was found to be 97 percent as accurate as ground inventories. —RM(210).

49. The timber wolf is in danger of extinction in the contiguous 48 States. Up to now, little was known about physical parameters of pups in natural wolf populations. Pups with relative weights less than 65 percent of standard have a poor chance of survival, whereas pups of at least 80 percent of standard have a high survivability. Pups born in 1972 were equally underweight, probably as a result of declining white-tailed deer densities in the interior of the Superior National Forest study area. This information will contribute to the development of management guidelines to insure the survival of this important animal. —NC(241).

50. Accurately estimating animal populations from traps is difficult because probabilities of trapping young animals are lower than trapping adults. To correct for this bias, a weighting factor has been developed for cotton rats. The method used, based on trapping studies of a known population, appears universally applicable and should improve estimates of animal population trends and age structure. —INT(196).

Rangeland management

51. High energy costs associated with production of feed grain and improved pastures are focusing attention on production of livestock on native range. Managers must recognize the limited quality of native forage species and use some supplemental feeds to boost the overall nutritional level in order to have a profitable livestock operation on southeastern ranges. There are 20.5 million acres of longleaf-slash pine-wiregrass ranges in the Southeast dominated by low quality shrubs or grasses. When grazing of native range is combined with improved forages, survival of calves increases 35-45 percent and weaning weights double. Range improvement through shrub control, fertilization, or plant conversion will greatly increase stocking capacity without excessive energy requirements. —SE(248,256,265).

52. Techniques for efficient inventory of multiple forest resources have been lacking. Researchers in Louisiana developed a procedure which was applied to forage resources for livestock and deer. A large-scale field test, encompassing nearly 7 million acres, demonstrated that comprehensive forest-range inventories can be conducted efficiently and at reasonable costs simultaneously with the nationwide Forest Survey. The procedure will assist in the assessments required by the Forest and Rangeland Renewable Resources Planning Act of 1974 (PL 93-378). —SO(263,838).

53. Livestock in southern pine forest-range require supplemental feeding. Researchers in Louisiana found that free-choice feeding of liquid supplements resulted in calf crops and weaning weights equal to or higher than those of cattle hand-fed cottonseed cake during winter. With liquid supplements during winter only, cows had lower production than either of the other alternatives. Net returns slightly favored the yearlong, liquid supplements. These results provide cattlemen with methods for supplementing cattle diets on the South's native range. —SO(257).

54. Economic relief to cattlemen, substantial quantities of red meat for consumers, and conservation of energy can be obtained through judicious grazing of forest-range. Calves weaned from cows grazing forest range in central Louisiana sold at a $10 profit, while those from improved pastures lost $90 per weanling calf, mainly due to high feed and fertilizer costs. These comparisons provide cattlemen and landowners alternatives for more efficient and economical cattle production. —SO(262).

55. Research in Colorado resulted in a model of root dynamics in shortgrass prairie. Losses and replacements in roots are greater than previously reported. The model provides new insight into the effects of the environment and herbivores on roots. The shortgrass prairie is unique in that 60 percent of the plant roots occur in the top 10 cm of soil. Total root biomass remains constant, irrespective of grazing intensity. —INT(155,244).

56. Grass and brush increased when Idaho ranges were protected from livestock grazing. Surprisingly, this increase was very small. Because of the number of years required for significant recovery of vegetation, protection from livestock is not a feasible method to improve these ranges. Other management practices are required to control sagebrush and increase grass. —INT(246).

57. Range managers often assume that the commonly-used measures of forage utilization reflect the amount of material actually consumed by livestock. However, considerable discrepancy often occurs between estimates of pounds of forage utilized and realistic appraisals of expected consumption. On native forb-grass summer ranges in southeastern Idaho and adjacent Montana, trampling accounted for 18 percent of the total standing crop "utilized" in pastures grazed by sheep in late summer, and 27 percent on open range grazed by herded sheep in late summer, and 18 percent on pastures grazed by cattle all summer. This study illustrates the magnitude of forage lost by trampling and indicates the need for quantification of trampling damage on many vegetation types and an evaluation of the physiological effects of trampling on individual plant species. —INT(250).

58. Forage and beef production on much semidesert grass-shrub can be increased by removing the shrubs mechanically. About 200 acres on the Santa Rita Experimental Range were chained in June 1970 to remove jumping cholla, staghorn cholla, pricklypear, velvet mesquite, and other shrubs. Mesquite on a second 200-acre area was killed with diesel oil. Recounts in 1974 showed that the density of staghorn cholla and jumping cholla on the chained area had been reduced to 2 percent and 6 percent of the original stand, respectively. Numbers of pricklypear in 1974 had been reduced only to 97 percent of the pre-chaining density. Chaining was very effective on mesquite. Compared to untreated range, grass herbage production in 1971 was 38 percent higher on the chained area and 76 percent higher on the mesquite-treated area. By 1974, once raw gullies on the chained area were lined with perennial grasses and several small head-cuts had healed. Control of shrub not only increases production of forage; it also helps to control erosion. —RM(254).

59. Yearlong grazing has been partly to blame for the poor condition of much semidesert range. Two alternatives to yearlong grazing—rest each year from November through April, and rest each year May through October--were tested on the Santa Rita Experimental Range. Mesquite-free range produced 43 percent more perennial grass forage than mesquite-infested range and average utilization, greater than 40 percent, was consistently detrimental to perennial grasses during the 10-year study period. But perennial grass stands improved greatly in very favorable years and declined sharply in drought regardless of other conditions. Neither rest period proved superior to continuous yearlong grazing. —RM(252).

Improving Social and Amenity Values

Environmental amenities- landscapes and open space

60. Landscape planners need methods for predicting the impact of changes in land-use on esthetic quality. Landscapes vary considerably in their vulnerability and resistance to changes in land-use. A method is described for predicting vulnerability of landscapes and for ranking levels of vulnerability for some of the more sensitive aspects. Results are useful in setting priorities for development of landscapes and in the preparation of environmental impact statements. —PSW(270).

61. Because pictures of outdoor environments are used many different ways, resource planners, educators, advertising executives, and others are interested in knowing how effectively a photograph duplicates or changes public opinion or feeling about an actual scene. Overall results of a recent study indicated that if a photograph of an outdoor scene adequately

depicts most of the variety in a scene, respondents have similar reactions (in terms of the adjectives they use to describe both the photograph and the scene). The results reinforce inferences from previous research in which photographs were used to measure reaction to scenic quality. Photographs of landscapes can be used to measure public preference for scenic quality and to obtain valid viewer reactions to proposed resource management practices. —NE(271).

62. Guidelines are needed for reducing the impacts of debris resulting from timber harvest on lands that are also managed for recreational and esthetic values. Relevant information has been developed for planning, harvesting, and interpreting timber management activities to enhance scenic beauty and help forest visitors understand what they see. Management can apply these principles to improve satisfaction of recreation visitors in environments disturbed by logging slash. —PNW(272).

63. Landscape planners are continually searching for natural vegetation that will enhance the scenic quality of the environment. Because of its beauty and ability to survive in rugged terrain, the canyon (or big-toothed) maple seems to be a promising candidate for enhancement of recreational lands that surround lakes in the Intermountain region of the United States. However, rate of seed germination varies considerably among individual trees. Propogation procedures and the mechanism of seedling survival are being studied under natural conditions. Eventually, selections with outstanding merits may be released to nurseries for commercial production. —INT(269).

Environmental amenities--wilderness

64. When demand for a given recreation activity far exceeds supply, planners must decide if other recreation opportunities could be developed as substitutes. Current research suggests that substitutibility among recreation areas and activities is suggestive rather than conclusive. It is important to recognize that use of wilderness, for example, may not be a substitutable recreation experience. —PNW(276).

65. The increasing demand for wilderness is the focal point of wilderness management problems. Results of all research done and sponsored by the Forest Service Wilderness Management Research Unit at Missoula, Montana, have been reviewed; and solutions to related management problems have been summarized. Topics covered include: the place of wildfires in wilderness managment, campsite and trail use, carrying capacity, user satisfaction, use measurements, wilderness permits, visitor characteristics, use simulators, and use distribution. This summary clarifies many of the challenges and issues of wilderness management. —INT(279).

66. To properly evaluate the feasibility of utilizing fire as a technique for managing vegetation in the interior-zone of the Boundary Waters Canoe Area, fire's historical role in the ecosystem needs to be understood. Research indicates that fire largely determined the composition and age structure of the area's forests; influenced nutrient cycles; and maintained the diversity, productivity, and long term stability of the area's ecosystem. The results of this research suggest that the use of fire is an ecologically viable approach to maintaining the natural ecosystem of this wilderness area. —NC(274).

67. To determine strategies for managing vegetation in the interior-zone of the Boundary Waters Canoe Area, knowledge of the composition, structure, and relationships of plant communities is needed. Ecological studies in the area indicate that the composition of plant communities is largely determined by: time since last disturbance, composition of the original community that was disturbed, and the severity of that disturbance. Other environmental factors are less important because of the narrow range of climatic conditions and the broad range of plant tolerances in the area. With this knowledge, managers can develop appropriate strategies to reduce the detrimental impact of such disturbances. —NC(273).

68. Managers are vitally concerned about the impacts of recreational use on campsites. Thirty-three campsites in the Boundary Waters Canoe Area were studied for 5 years to determine the impacts of use on soils and vegetation. The effects of user impact tended to level off after the first 2 years. Results suggest that campsites should not be closed or campsite-use rotated in order to avoid user impacts. Criteria are provided for designing and locating campsites. These criteria consider the limitations of the environment and the types of people who use it. —NC(281).

69. Wilderness-use data can be tabulated in an infinite number of ways; some tabulations can be extremely valuable to managers. Analysis of data from user permits in the Boundary Waters Canoe Area shows how management can: understand trends or changes in use; determine where and when the regulation of visitors may or may not be necessary; select locations for public meetings and distributing news releases; and plan daily work schedules. The information presented underscores the importance of identifying summaries that are important for management purposes. —NC(277).

70. Because some wilderness visitors do not obtain permits, use estimates based on completed permit data need to be corrected. In a study of the Boundary Waters Canoe Area, 88 percent of the summer visitors sampled had a permit. Groups without permits were primarily daytime motorboaters. Reasons for noncompliance are not clear, but most of these parties probably were either unaware of the need for permits or did not entirely understand regulations of the area. By deriving expansion factors, based on the percent of groups without permits, total use can be estimated by multiplying the factor by the raw use totals. —NC(278).

71. Methods are generally inadequate for measuring how wilderness recreationists define a quality experience. A method has been described and tested for measuring recreationists' aspirations for, and perceptions of, conditions related to a wilderness experience. Comparison between aspirations and perceptions allow managers to identify specific sources of satisfactions and dissatisfactions associated with the experience, and to measure the relative contribution of each to overall satisfaction. The results are useful to managers because the elements evaluated by users are conditions that wilderness administrators can manage for—such as congestion, types of facilities, adequate maps, and fishing conditions. —NC(282).

72. To insure that wilderness management actions relate to public needs and values, comparisons need to be made periodically between the manager's and the user's feeling about wilderness values. Wilderness managers and summer canoeists were studied in the Boundary Waters Canoe Area to determine whether the two groups differed in their wilderness motivations, attitudes, preferences, and perceptions. Differences that exist suggest that management services will be less than optimal if the manager's decisions reflect his own attitudes and perceptions. —NC(283).

Managing recreational opportunities

73. Developers of commercial outdoor recreation enterprises and public park planners need factual information on trends in recreation participation. Analysis of 8 years of data on camp-

ing participation (reported by a panel of 459 camping families) revealed that: 51 percent of campers were either camping less or had dropped out of the camping market; campers increasing or decreasing their rate of participation were more likely to have experienced a change in their style of camping; and changes in camping style were either toward a more primitive type or toward season-long rentals and advance reservations at commercial campgrounds. Both trends in volume and style provide important clues for planning future facilities. —NE(302).

74. Potential developers of commercial campgrounds need to know what factors account for a successful recreation enterprise. Interviews of 529 commercial campground operators in 12 northeastern States indicated that success of an enterprise was strongly related to advertising expenditures. Operators who spent more than $5 per campsite for advertising grossed an annual average of $161 per campsite. Operators who spent less than $5 per campsite advertising grossed an annual average of $95 per campsite. These and other findings provide private investors with important information on campground development opportunities. —NE(288).

75. Managers frequently do not know how visitors react to actions designed to alleviate problems of overuse. Nonetheless, such reactions can play an important role in shaping management decisions in the future. A survey of skiers and hikers in the heavily used Tuckerman Ravine area of the White Mountain National Forest revealed that different user populations perceived overuse of the area in different ways. For example, spring hikers were less opposed to limiting visitor use than spring skiers or summer hikers. Both spring and summer visitors opposed more facility development, but recognized the need for more camping areas and better enforcement of user regulations. Results of the study influenced the management decision to use an overnight permit system to control overuse of the area. —NE(295).

76. If future recreation demands are to be met, management decisions must incorporate the opinions of a wide range of recreation-user groups. A survey of 157 campers and 281 boaters at the Allegheny reservoir on the Allegheny National Forest revealed that user and manager attitudes often were quite different. Furthermore, different kinds of users had different attitudes about: procedures to control recreation use, fee policies, zoning of recreational activities, procedures for law enforcement, and development of facilities. The study describes how to make recreation management decisions that minimize negative reactions from recreationists. —NE(304).

77. Better methods are needed to inform certain segments of the recreation public about rules and regulations. A survey of 588 campers on the Allegheny National Forest in Pennsylvania indicated that new campers, young campers, and campers not familiar with the camping area are particularly unaware of rules. Communications efforts directed to those specific groups will lead to a better informed camping public. —NE(306).

78. A democratic, technology-oriented society must anticipate and avoid changes that will detrimentally affect its basic life support systems of air, water, soil, flora, and fauna. Using the Delphi research technique, a panel of 900 experts provided forecasts of 125 future events about the Nation's natural environment. Events were grouped into five categories: natural resources management, wildland recreation management, environmental pollution, population-workforce-leisure, and urban environments. These perspectives on the future provide a basis for dealing more effectively with future environmental problems. —NE(307).

79. The ability to accommodate wildlife in the national economic system is one of the most significant challenges facing managers of natural resources. A recent survey indicated that wildlife values are emphasized only in situations where wildlife already exists in relative abundance. Forecasts of future wildlife priorities and benefits suggest that future demand for wildlife will involve non-consumptive benefits that accrue largely to urban populations. Results of this survey will help wildlife managers reorient programs to the changing needs of the American public. —NE(309).

80. Recreation resource managers and planners need a clearer understanding of how social factors and the physical features of the resource influence their decisions in urban, rural, and wildland management. Examination of the decision-making processes in four public land management agencies revealed that the highest priorities are given to elements that reflect immediate circumstances surrounding the decisions. Present recreation demand, available operating budget, and similar future recreation demand—in combination with physical characteristics of the resource base—were the major considerations. Results permit land managing executives to better understand how other agencies arrive at decisions on recreation management. —NE(308).

81. Increasing demands for fish and game call for more explicit management techniques in order to produce the experiences desired by sportsman. A "multiple-satisfaction approach" describes how to segregate a game management program according to the various kinds of experiences it provides. Using this technique, managers can appraise the extent of resources invested in each kind of experience and compare that investment with game harvested, hunter-days of participation, or other relevant data. The appraisal helps managers to better define and set standards for maintenance of the quality of hunting and fishing experiences. —PNW(297).

82. Land managers need new methods to analyze public reaction to land management issues and problems. A system has been developed that not only analyzes but also stores and retrieves information on public opinions submitted to managers via personal letter, petition, report, or other means. The system allows managers to quickly summarize public involvement data for decisions on resource management. —PNW(290).

83. Pertinent principles in communications research are not being applied to maximum advantage in environmental education and interpretation programs. Twenty-eight principles of communication are presented and used as an index to 57 annotated references. Results will help specialists in education and interpretation to use words, symbols, analogies, situations, and stereotypes that audiences will understand. —PNW(292).

84. Communication skills are not always used as effectively as possible by resource managers when they attempt to interpret ecological information for the public. Research has shown that to have maximum viewer interest, the interpretation must be dynamic, rewarding to visitors, easily obtained, tailored to diverse visitors, and meaningfully structured. Adaptation of these principles will improve the effectiveness of interpretation by attracting more visitors and holding their attention longer. —PNW(313).

85. Managers of campgrounds need techniques for maintaining vegetative cover without restricting visitor use. Ground cover vegetation was reestablished in a heavily used area through an intensive water-seed-fertilizer combination treatment at a cost of 29 cents per visitor day. Intensive vegetation management, combined with programs to inform and enlist campers cooperation, can be used to create and maintain attractive campsites. —PNW(287).

86. Land managers are continually seeking more effective means of involving diverse interest groups in the development of agency goals. Research suggests that the use of small working groups, with sustained interaction among representatives of conflicting interests, offers a viable solution. If management goals are to reflect informed opinion, compromise, and opportunities for mutual advantage, then managers and conflicting interest groups must interact sufficiently to identify tradeoffs. —PNW(314).

87. Resource managers need to know how recreational carrying capacity can serve as a criterion in the allocation of recreation resources. Several concepts are described that meet this need. By reviewing the potential consequences of alternative strategies, managers can better define the kinds of satisfactions to be provided, who the principal recreation clientele will be, and what recreational opportunity options are precluded for a given decision. Such an assessment of social impact is required by the National Environmental Policy Act of 1970, but little has been accomplished up to now, on how such impacts should be articulated. —INT(310).

88. How to obtain and effectively use public input in making resource management decisions is a problem that confronts resource administrators at every level of government. Processes for obtaining, analyzing, and evaluating public input have been described, and the importance of both the quality and quantity of public input discussed. By increasing public participation in the decision making process, public agencies may be able to avert mistakes and diminish ex-post-facto confrontations. —PNW(299).

89. Some of the most challenging questions that resource planners ask are: What do natural environments mean to people? How do different recreationists perceive one another? and how do recreationists feel about managers of natural environment? Research has quantitatively described the difference and similarities in how three groups of recreationists—auto campers, wilderness hikers, and picnickers--perceived each other, the natural environment, and resource managers. Results contribute toward a better understanding of the way recreationists relate to outdoor environments and what they expect from those environments. —NE(305).

90. There is a need for recreation researchers to work closely with land managers in order to relate research findings to management needs. The Marquette Workshop was one effort to promote this interaction. The proceedings contain 15 papers whose subjects include social and esthetic considerations, economic problems, and design and development of sites. These state-of-the-art papers are intended to summarize new technology and information for recreation management programs. —NC(311).

Environmental Tree Culture

91. Urban microclimates are characterized by local extremes of temperature, solar and terrestrial radiation, and wind speed. Strategic location of tree stands in urban areas can ameliorate these severe conditions. Shielding of terrestrial radiation and interception of solar radiation by trees are major factors in reducing radiation and temperature extremes. Local rates of air flow may be reduced by vegetation. City planners and urban foresters can use this information to provide more desirable microclimates in cities. —NE(741).

92. Many of the sounds present in urban atmospheres are unwanted. Sound barriers in general fail at night because of refraction over the barrier. However, trees and shrubs, particularly when used with land forms and structures, can play a significant physical role in noise control. This information can be used by city planners. —NE(742).

93. The need to quickly alleviate a noise problem often does not allow time for development of effective shrub-tree barriers. Sound levels can commonly be reduced by 10 to 15 decibels (less than half as loud) with 12-foot-high land forms combined with wide belts of tall trees. Trees or solid barriers may be used separately, but the combination provides more uniform control for a greater distance than either one alone. Effectiveness of tree-covered land forms is now quantified and being used by highway engineers, landscape architects, foresters, and others to reduce noise from disturbing to acceptable levels. —RM(740).

94. Relatively narrow, but dense and tall shrub and tree barriers—in conjunction with walls, terraces and fences--have now been found to reduce suburban noise from a 70 to 75 decibel level (rather noisy) down to a 62 to 67 decibel level (generally satisfactory for daytime outdoor environments). Conifers and broad-leaved evergreens are more effective on a year-round basis than deciduous trees, and the range of suitable material is diverse. These data can aid the nurserymen and others designing effective landscape plantings for the reduction of suburban noise. —RM(743,744).

95. Many older windbreaks throughout the Great Plains need renovating— not only to improve their vigor and effectiveness, but for foresters to keep abreast of changing agricultural practices. Eastern redcedar, ponderosa pine, and Austrian pine seedlings were planted in a portion of a 10-row shelterbelt where half the rows were removed and subjected to five cultural treatments. Survival and development were best with complete mechanical cultivation, mowing, and complete chemical spray; and poorest with chemical and mechanical strip treatments. Site preparation and cultural treatments are recommended for replacing rows of deciduous trees with evergreens in decadent windbreaks in order to prolong and increase the effective life of established windbreaks. —RM(745).

96. Multiple leaders often develop on sheared Scotch pine Christmas trees. The deformed trees which result require considerable labor to correct. Recent research in Kentucky shows that removing all but one potential terminal bud from the tree leader during the dormant season reduces the number of trees with multiple leaders. Scotch pine Christmas tree growers therefore benefit from this simple procedure, which can be done during a slack time in their schedule. —NE(746).

Ecology and Classification of Natural Vegetation

97. Limited data have been collected for the forest vegetation on the western slopes of the Cascade Range in Oregon. Twenty-tree forest communities, arrayed along moisture and temperature gradients, have been provisionally recognized in two distinct forest zones, the *Tsuga heterophylla* and the *Abies amabilis*. This information is being used to stratify areas for extensive ecological research under the International Biological Program and for silvicultural prescriptions. —PNW(634).

98. Cascade Head Experimental Forest is a facility established for research on the very productive coastal "fogbelt" hemlock-spruce forests, yet little has been reported on the fauna of this coastal area. An annotated checklist is now available and includes 9 amphibians, 2 reptiles, 35 birds, and 40 mammals. A standardized habitat classification is presented in an effort to correlate the vertebrates in a meaningful way to their environment. Data will provide a

valuable basis for future research on fauna which inhabit hemlock-spruce forests. —PNW(649).

99. Fields of thin-leaved huckleberry (*Vaccinium membranaceum*) are dwindling in area and productivity throughout the Pacific Northwest. Greenhouse trials in Oregon indicate that nitrogen has a greater effect than potassium or phosphorus on huckleberry seedling growth. Fertilization of wild huckleberry fields with ammonium sulfate at rates of 40-160 pounds per acre greatly stimulates vegetative growth. These findings provide a physiological data base for future berryfield fertilization. —PNW(651).

100. Species identification of young tree seedlings is often difficult because most morphological descriptions are based on mature specimens. Studies in Wisconsin have resulted in the construction of an identification key based on seedling and needle characteristics of eight North American spruce species. Needle shape, margin separation, and needle apex are important characters in the key. Nurserymen and researchers can use this key to make difficult species identifications in seedlings. —NC(731).

101. Forest and land-use planning is actively underway for both public and private lands in New England, but basic information relating vegetation to soils and physiography is scarce. Transects on an undisturbed and a cutover mountainside in New Hampshire provided information on maximum tree sizes, species composition, and species limits related to elevation, as well as probably trends in species movements up and down slope. When cutting is eliminated, the natural ranges of beech, yellow birch, and sugar maple move uphill to their upper limit of about 2,800 to 3,100 feet in elevation, while spruce and fir ranges tend to retreat. This information currently provides the best foundation for the use of elevation in forest land use planning in the White Mountains of New Hampshire and similar adjacent areas. —NE(643,645).

102. Public interest in wilderness and natural areas is high, but little is known about the long-term effects of forest preservation on vegetation, soils, and streamwater. A study of age distribution in virgin northern hardwoods in New Hampshire indicates that: (1) The stand is moving towards stable populations of beech, sugar maple, striped maple, mountain maple, and hobblebush; (2) the humus has stabilized at a depth no greater than that found in stands cut 70 or 80 years before; and (3) the streamwater contains summer concentrations of NO_3 ranging between 1 and 5 ppm. The results indicate that preserved northern hardwood forests will tend toward reduced tree species diversity, stable humus depths, and, possibly, fairly high levels of NO_3 in the streamwater. —NE(644).

103. With increased interest in maintaining species diversity, better knowledge of ecological requirements of herbaceous as well as timber species is needed. A lay-level article describes the habitat distribution of flowering herbs in the pine barrens of New Jersey and contrasts floral composition of undisturbed and disturbed areas of various types (e.g. logged, burned). Information can be used by land managers and recreationists to locate popular wildflowers. —NE(646).

104. Understory plants in pine stands aid in nutrient cycling and provide shelter and food for game. A survey of a 33-year-old loblolly pine plantation in the Piedmont of North Carolina found 19 families, 45 genera, and 59 species of vascular plants. Twenty-one species of *Fabacea* (formerly *Leguminosae*), most of which fix nitrogen, and two other species known to fix nitrogen were identified in the survey. Propagation of selected pine species and development of management methods for their growth may improve the soil in southern pine plantations. —SE(639).

105. A current inventory of rare and endangered tree species was prepared to aid in their study, protection, and preservation. Thirty-five of the 96 species of conifers (cone-bearing evergreens) native to the continental United States are rare or local. Occurrences of rare or endagered trees are mapped and cited by public forests, parks, and other preserves. This compilation provides essential information for those who study, manage, and protect rare conifers. —WO(735).

106. The numerous native and introduced tropical forest tree species of Puerto Rico require special, detailed studies for their identification. A new illustrated reference contains descriptions and drawings of 460 species, briefly describes 40 other species, and provides keys to all 500 species. Common names, including those from other countries, are given and indexed. This reference is useful over large areas in tropical America as well as along the southern border of the continental United States, where tropical trees are planted. —WO(736).

107. An up-to-date guide for identfication of trees is needed in Alaska, particularly because of the rapid development of land-use planning and forestry programs. A new guide has been prepared that describes and illustrates 32 species of native trees, mentions briefly six species of shrubs rarely reaching tree size, and contains keys, notes on occurrence and uses, small maps, and a vegetation map. This nontechnical reference is for all who are interested in trees, including foresters and land-use planners, residents and tourists, students and teachers, scientists and conservationists. —WO(738).

108. Detailed maps of natural distribution of plant species are essential for many uses, such as in land-use planning and management, wild plant utilization, and seed collection. A new atlas maps distributions of 82 species of Alaska trees and common shrubs. Also, 23 general maps summarize environmental factors and supply background information on geography, geology, climate and vegetation. This reference aims to provide preliminary answers about where each species grows and why. —WO(739).

Improving Environmental Quality Through Fire Management

Fire prevention, hazard reduction, and prescribed burning

109. Man-caused fires are still a major problem in the deep South. A personal contact program in fire prevention reduced man-caused wildfires in a Louisiana parish 55 percent over a 5-year period. Guidelines have been developed for planning and conducting additional personal contact programs for other areas. Decreased fire control and fire damage costs are the overall result of these efforts. —SO(550).

110. Prescribed fire is used extensively in forest management throughout the southern United States. During 1972, fire was used on almost a million acres of forest and agricultural land in Georgia alone. It is important to be able to assess the total environmental impacts of open burning. Quantity and quality of smoke produced by fires sampled to date indicate particulate production rates vary between 15 and 158 pounds per ton of fuel. Information is being assembled to establish relationships which exist between fire type, fuel type, fuel moisture content and particulate emission rate, concentration, and size distribution. Methods for determining particulate source strength emission factors for low-intensity prescribed fire have been developed. A smoke volume model has been developed with prediction accuracies of 75 percent or better based on limited test data. These efforts will continue to pro-

vide needed input to more completely assess the environmental impacts of prescribed burning. —SE(556,566,572,573,575).

111. The widespread use of prescribed fire in the South has brought about a need for burning guidelines. Such guidelines are necessary to maximize the positive environmental effects while minimizing the negative impacts. To date, guidelines for burning have been prepared for several land management goals including both site preparation and enhancement as well as hazard reduction. In the southeastern Coastal Plains, prescribed burns every 3 years forestall possible wildfire damage. General guides have also been developed to reduce the impact of smoke and to meet current local and regional regulations and standards. —SE(544,557,560,561,563,567).

112. Television public service directors in California were asked to rate fire prevention film spots they had received from the California Division of Forestry. Most directors rated them high in technical quality and interest. Delivery of the films by a fire prevention officer impressed directors favorably. However, fire prevention announcements generally ranked low in likelihood of selection for showing. Showing might be increased by giving the announcements a local flavor, tying them in with public health, conservation, and the environment, and giving greater attention to personal delivery of the films by fire prevention officers at an appointed time. —PSW(542).

113. Most people in Butte County, California listen to the radio and watch television, but they differ widely in the way they use these media depending on their demographic, social, and economic characteristics. Fire prevention planning should capitalize on these differences in developing mass media communications. In improving the prevention message dispersion, we can ultimately save fire control dollars and needless waste. —PSW(554).

114. In fuel types where fire propagation is primarily through the crowns of vegetation, the moisture content of the living fuel has a major effect on the rate of fire spread and on fire intensity. Seasonal variations in living fuel moisture often exceed 200 percent. New sampling methods and a simple "do-it-yourself" technique have been developed for obtaining the moisture content of living fuel for fire control and prescribed burning applications. This information can help the fire boss in his decisions about fire control and fire use. —PSW(545).

115. A substantial reduction of railroad-caused fires in New York State is linked to the cooperative efforts employed by the State's Department of Environmental Conservation. Among these efforts is a program of routine spark arrester maintenance and the use of a pyrometer sensor for isolating defective brake shoes and hotboxes. Additionally, a cooperative study with USDA Forest Service investigated the discontinuous application of phytocide chemicals on steep, erodable rights-of-way to reduce fuel hazard without environmental impairment. —NC(558).

116. Forest residues present fire problems, and are, in part, a function of existing utilization standards. Trends in log prices are a key to market conditions, and such information is needed by both industrial and public forest managers. A sharp upturn occurred in prices for all log species in 1973 in Oregon and western Washington. This has encouraged greater logging utilization, especially where low quality logs, formerly left as residue, can be substituted for higher priced logs in the production process. More complete utilizations reduce the fire hazard. —PNW(541).

117. Utilization of wood residue provides more material for products and energy and at the same time reduces fire hazard and environmental impacts of converting the timber resource. The latest national data available are used to present volume and location of unused forest residue, primary mill residue, secondary plant residue, and bark. Information on residue location and availability is needed by manufacturers looking toward possible large-scale use of residues in new plants or processes. —PSW(552,553).

118. Information is lacking concerning the use of helicopters as a forestry tool. There is a specific need to harvest commercial timber from steep slopes where access is difficult. This need has led to public concern over the adequacies of conventional logging systems. General information has been developed summarizing factors relevant to the productive and safe use of helicopters for timber harvesting, with emphasis on candidate helicopters and their characteristics. Comparisons of yarding rates with costs for helicopter, balloon and cable yarding systems have been made. This initial information provides the basis from which more environmentally sound resource management decisions can be made. —PNW(551,570).

119. Environmental effects of excess, unwanted, living or dead woody material in forest areas are poorly understood yet often of great importance to such forestry considerations as nutrient cycling and soil management, wildlife habitat, forest regeneration and growth, esthetics and recreation, forest fire management, fish habitat, and water quality. Treatments of these residues, with or without fire, have substantial effects on the environment. A collection of articles by 29 authors defines the present level of knowledge and identifies the residue-related problems most in need of research attention in the Pacific Northwest in various components of the forest environment. —PNW(547).

120. Prescribed burning and forest wildfires produce smoke that may result in an air pollution nuisance. The amount of smoke produced varies with fuel and burning method, and the dispersion of the smoke varies with fire characteristics and weather conditions. Smoke management is a necessary part of quality forest environmental management where wildfire or prescribed fire are present. —PNW(546).

121. Slash is often burned to reduce the hazard of accidental wildfire, but the need for regulating air quality must be weighed against the hazards from wildfire. Thus, evaluation of this pollution source depends on a detailed knowledge of the nature and amounts of emissions from slash burning. Recent tests showed that the smoldering phase of combustion is of major importance to air pollutant production during slash burning. The initial 80 percent of the fuel burned accounted for only 20-30 percent of HC and CO emissions. This suggests that a rapid mop-up of slash burns could substantially reduce air pollutant production. —PNW(568).

122. Improved techniques for precommercial thinning and slash treatment are needed for overstocked pine stands in eastern Oregon. The Trakmac machine has a boom-mounted cutting disc, enabling the operator to select individual trees for cutting, sever the stem near ground level, and treat the resulting slash in one operation. Both branches and boles of cut trees were reduced to small, well-scattered pieces. This treatment speeds natural deterioration and results in an immediate reduction of fire hazard. —PNW(574).

123. An understanding of emissions from open burning of forest residues is needed to avoid negative environmental impacts and meet local air quality regulations. Study in ponderosa pine slash showed average particulate emission to be 12.5 lb/ton of fuel burned while Douglas-fir slash averaged 6 lb/ton of fuel burned. Eighty-two percent of the particulate mass was in the submicron range. Particle size distribution did not depend on fire intensity while flaming still existed. Infor-

mation developed in this study will assist in designing burn prescriptions which will result in minimum emissions and attendant air pollution. —PNW(569).

124. Land managers need to know how much crown slash will be created by various harvesting methods when developing management plans and strategies. The amount of slash produced determines the fire hazard due to logging. Study results in Oregon and Washington indicate Douglas-fir biomass (slash) less than 7.62 cm in diameter can be predicted from tree diameters, an easy-to-obtain measurement. Several prediction equations were developed for determining tree crown residues. Data and procedures which were developed provide objective quantitative assistance to land managers for sound multiple use decisionmaking. —PNW(576).

125. Development of conflagrations is dependent upon—among other factors--weather, terrain, and large accumulations of residue or fuel. Theoretically, by strategic manipulation of residues, the forester is able to trade routine cost of hazard reduction for cost of emergency conflagration suppression. He cannot control the weather or terrain. Fuels accumulate in natural systems, but man's actions may greatly modify the nature of the fuels, and thus, the hazard. Each fuel component has its own characteristics, thus making its specific contribution to hazard. Integration of fuel management planning with other phases of forest management planning will help to achieve a pattern of fuels and low hazard areas compatible with fire management and environmental objectives. —PNW(559).

126. A need exists to reduce ground fuels and abate the wildfire hazard in established stands of west-side Douglas-fir in Oregon and Washington. Initial results of limited study indicate that from about 40 percent to over 80 percent of roundwood fuels, depending upon diameter, can successfully be removed using fire. Some tentative prescription criteria have been developed. The information provided, along with burning procedures, will assist land managers in meeting their multiple-use objectives. —PNW(571).

127. A question facing land managers is: "Exactly how much does increased utilization of residues reduce the fire hazard, compared to conventional utilization?" Fuel and fire potential in clearcut lodgepole pine, (*Pinus contorta* Dougl.), was compared after stands were logged to near complete and conventional utilization standards. Logging to such standards reduced fire potential to a point that no further fuel modification should be required for hazard reduction. Logging to conventional utilization standards left the fire potential high enough to warrant fuel modification for hazard reduction. Results are useful for planning timber sale activities. —INT(543).

128. In 1972, the Forest Service initiated a practice of allowing lightning caused fires to burn unchecked in certain wilderness areas so that fire could assume a more natural ecological role. The first real test of the concept came in the summer of 1973 when the Fritz Creek Fire in the Selway-Bitterroot Wilderness Area was allowed to burn for 42 days and reach a size of 1200 acres. Analysis of this fire's effects clearly demonstrates that with careful study, sound fire management prescriptions can be written to allow fire to play a more natural role in wilderness ecosystems. Prescriptions must, however, be applied carefully and with full attention to proper suppression techniques when suppression action is required. —INT(585).

129. It is important that the land manager have a general perspective as to the amount, reason, and conditions under which prescribed fire is used within his general geographical area. During the period 1968-1972, prescribed fire has been used on 76,743 acres in Minnesota, Wisconsin, Michigan, and Ohio. Most of the burning has been for wildlife habitat work and was conducted in late April and early May or late July to early August. This summarized information provides land managers a basis on which to plan and to compare their current operational procedures. —NC(548,549).

130. Resource managers need procedures to take some of the guesswork out of the decisionmaking process. A series of computer generated (CALCOMP) graphs has been developed to display potential fire behavior in logging slash of seven northeastern tree species. These objective criteria can be used to help decide whether slash treatment is needed, treatment method alternatives, and how priorities could be assigned when several areas require treatment. —NC(565).

131. Sprouts of many hardwoods are favored foods of white-tailed deer, but generally are undesirable for timber production because of poor quality. Sprouts from hardwood trees killed by a prescribed fire on the Chippewa National Forest, Minnesota, were most vigorous from basswood, red oak, and paper birch. American elm, bur oak, ironwood, and red maple were intermediate sprouters, while sugar maple and yellow birch sprouted poorly. Burning encourages sprouting close to the ground line which is beneficial to red oak, and probably other species, because decay entrance from the parent tree is reduced. —NC(564).

Fire management methods and systems

132. The field of fire management has generated a terminology to express the role of fire in wildfire suppression. However, this terminology has developed on a regional basis. Adoption of the proposed terminology would promote a universal understanding by providing a simple common definition for the fire suppression terms. Improved communications would result. —SE(587).

133. Computer calculations of National Fire Danger Rating System (NFDRS) values can be costly and differ fron those developed by using tables. Although differences between table- and computer-derived NFDRS values do exist, study indicates no significant problems will result. Guidelines have been developed to assist computer timeshare users in attaining the most economical machine use. Continued computer use and application in danger rating will enhance our ability to store and retrieve data for future use as well as improve daily utilization. Development of a computer system will also assist us in all forms of planning. —RM(586,596).

134. Because of unusually wet weather during early 1973, the Bureau of Land Management was faced with more than normal grass fuels over much of the Southwest. This resulted in an urgent need to prepare a fire plan for 600,000 acres of high-value, high-fire potential lands in Arizona. Agencies cooperated in making and evaluating the plan (using the FOCUS simulation model) in less than 30 days. The emergency fire plan included all phases of fire management and combined basic research, applied research, and practical knowledge in its preparation. —PSW(589).

135. Most computer data storage and retrieval systems for map-type information require much hand coding and computer storage capacity. A procedure has been developed that requires only the description of the map area boundary. This technique describes the boundary as a set of short line segments that can be defined in terms of a multi-dimensional polygon. Preliminary tests show that about one-tenth the hand labor and computer storage is required for this method compared to other techniques. As additional support for manage-

ment, a computer system has been developed and put into use that quickly and inexpensively prepares three-dimensional histogram charts of computer fire statistic records. The system allows fire control planners to visualize their fire occurrence problems at a glance where previously they would have spent many hours reading through historical records. —PSW(591,592).

136. Conflagration fires account for most of the fire damage and loss of life from wildland fires in southern California. Quick suppression of wildland fires with conflagration potential in this area is made difficult by a distinctive complex of fuel, topography, and weather; and is further complicated by the influx of people and suburban developments into the wildlands. Enlarged fire control forces, improvements in firefighting techniques, intensified fire prevention, and better organizational structures appear to offer little hope for alleviation of the conflagration problem. The best solution is the modification of the vegetation to reduce fire energy output through the creation and management of fuel type mosaics. —PSW(584).

137. The Administrative and Forest Fire Information Retrieval and Management Systems (AFFIRMS) provide an interactive national computer network for automation of the National Fire Danger Rating System and message traffic routing. AFFIRMS is a user-oriented system. The user's guide contains instructions for use of all thirty AFFIRMS commands, a terminal operations manual, and a complete directory of error messages, their meanings, and appropriate user action to correct each error. The guide is in use by the Forest Service, National Weather Service, Bureau of Land Management, and State forestry agencies for training and operation nationwide. —RM(555).

138. The most cost-effective means of wildland fire protection for the Santa Monica Mountains in California is for all houses to have fire-resistant roofs and 100 feet of brush clearance. If this plan were implemented, strucutral losses could be reduced by almost a factor of ten, decreasing the present average burn rate of 60 houses per year to a rate of only 7 houses per year. Although wildfire is inevitable in the Santa Monica Mountains, homeowners, developers, local government officials, insurance executives and bankers should be made aware that certain protective measures can greatly reduce wildfire losses. —PSW(594).

139. Oak-hickory forests are important natural and renewable resources in the eastern United States. Estimation procedures for future sawtimber losses due to fire-caused wounds are given in terms of: 1) Lumber value in dollars, 2) volume in board feet, 3) length of defect, and 4) area of defect. The predictive models apply to all major oak species endemic to the oak-hickory forest types. Application of these procedures should help avoid needless loss of an important forest product. —NC(590).

140. In 1971, the Carrizo Wildfire on the White Mountain Apache Reservation in Arizona burned 57,335 acres of commercial forest land. Some of this area had been treated by controlled burning a year earlier. Although much timber was damaged or killed, the fire had many beneficial effects—range and wildlife improvement through increased forage production, thinning overstocked young timber stands, and consumption of surface fuels resulting in reduced fire hazard. Fire studies are underway to determine the influence of controlled fire and wildfire on a ponderosa pine ecosystem. —PNW(616).

141. Wildfires in Alaska can produce considerable smoke under specific meteorological conditions. In a region so dependent upon air transportation, wildfire smoke could present problems. Records of 21 stations were analyzed for the occurrence, persistence, and related visibility resulting from summertime wildfire smoke and haze in interior Alaska. Smoke persistence and impaired visibility were not found to the extent previously assumed. —PNW(581).

142. Practical methods for inventorying volumes of downed woody material to provide an objective basis for managing debris have been lacking in the past. Procedures which have been developed and prepared in handbook form are quick and easy to use and can be applied to naturally fallen debris and slash. Instructions show how to estimate weights and volumes of downed woody material, fuel depth, and duff depth. Inventorying downed woody material can help land managers practice fuel management, plan for prescribed fire, estimate utilization potential, and communicate in exact terms about their debris problems. —INT(582).

143. The fire manager needs to know where to apply chemical retardants, in what concentration, and in what form for various fire situations and fuel types. Results of a series of tests showed that the proportion of retardant retained on fuel arrays increased as the fuel diameter and surface roughness of individual fuel elements increased. Equations describing retention were developed and extended to actual field situations; results agreed with published findings on the transmission of rain. The results of the retardant drop tests provided equations that relate retardant retention to fuel size, and illustrated the types of distribution that can be expected under tree canopies. This information contributes to guidelines for the use of retardants to control wildland fires. —INT(578).

144. Wildland vegetation can be quantified into various classes of fuels, but it also needs to be appraised for fire potential to aid in fire management activities. Elements making up fuel appraisal are defined and a concept for appraising fuels, using inland Douglas-fir (*Pseudotsuga menziesii*) as an example for fuel, is presented. Fuel appraisal elements that can be used now include rate of spread, fire size, fire intensity, and crowning potential. The concept presented can provide the land manager with a decisionmaking tool for quantifying fuel appraisal. —INT(579).

145. An estimated 17 million gallons of retardant valued at 23.5 million dollars were delivered in 1970. This widespread use presents an urgent need to increase the efficiency and safety of fire retardant air operations. Considerable effort has gone into the development of static and drop test data including simulation models. Rheological properties, aerial drop behavior, dispersion characteristics, and wetting—out properties have been tested and evaluated. Various forms of delivery systems--including large military helicopters--and delivery criteria have been tested. Guidelines in an easily used form to help air tanker pilots, air attack specialists, and ground personnel obtain optimum retardant coverage under various operational conditions have been developed. The basic research and guidelines provide means by which safe, productive, and economical use of retardants can be implemented. —INT(577,580,597,598).

146. Because of both safety and cost implications, we must be able to assess the severity of fire retardant-caused corrosion on air tankers and mixing plants. In the laboratory, the effects of five operational retardants on ten aircraft and pump alloys were investigated. Results indicate, in part, that fire retardants currently used can be corrosive to aircraft, and that corrosion rates vary for each alloy and retardant formulation combination. Only stainless steel alloys were unaffected by commonly used retardants. However, the use of additional inhibitors can reduce corrosion markedly on any of the alloys tested. Study results and recommendations provide the basic

information to develop safe products with acceptable corrosion levels designed to meet field application and operational requirements. —INT(588).

147. Improved capabilities for safely attacking forest fires in a wide variety of terrains are urgently needed. The feasibility of using large military type rotary winged aircraft (Chinook helicopter) was evaluated. The Helicopter Modular Airborne Fire Fighting System (H-MAFFS) test demonstrated large helicopters can be used to deploy forest fire retardants. No aircraft equipment modifications are necessary. Retardant concentrations can be easily controlled as can drop altitudes. H-MAFFS is quickly off loaded (30 minutes or less) making the aircraft immediately available for other missions. No adverse helicopter control or emergency jettison procedure problems were encountered. Use and development of multipurpose retardant aircraft systems allows utilization of existing equipment and minimizes capital investment in specialized aircraft ultimately saving considerable funds while improving efficiency. —INT(583).

148. Legitimate concern for air quality requires that the impact of smoke from prescribed fires must be minimal. Twenty-two documented 10-acre slash fires in the western larch/Douglas-fir type of western Montana were analyzed for factors related to ultimate smoke column heights. Contrary to accepted theory, atmospheric stability was not of great significance in describing smoke rise. Factors directly related to fire intensity were the important descriptors of column height. Management guidelines based strictly on meteorological factors are possibly too restrictive and inaccurate in representing actual smoke behavior, hence many burning opportunities are being missed. —INT(607).

149. Development of understory burning techniques requires the establishment of quantitative relationships between preburn conditions and fire effects. Twenty-two experimental plots in a Douglas-fir/western larch stand in western Montana were burned to determine the effects of prescribed fire on fuels, vegetation, soils, nutrient cycling, and air and water quality. These fires were conducted over a wide range of fuel and weather conditions to produce a range of fire intensities. Preliminary results indicate that it may be possible to accurately predict the effects of various types of fires on these forest lands. —INT(614).

150. The Bureau of Land Management used a converted DC-6B airliner as a retardant bomber during the 1971 and 1972 fire seasons in Alaska. Daily minimum prices, daily minimum and hourly rates, and cost per retardant mile or gallon compared favorably with other aircraft currently in use. —INT(595).

151. A recent publication contains 910 sets of forest fire ecology questions mailed to 302 land managers and scientists throughout the western United States and western Canada. The questions cover the entire spectrum of environmental parameters affecting and affected by fire. The question sets collectively express the most important information needs for those managers who require an understanding of the ecologic effects of fire. —INT(599).

152. Major considerations regarding fireline construction in interior Alaska are protection of the fragile tundra environment and costs. Evaluation was made of a Franklin articulated all-terrain log skidder equipped with a double-backup pump system for retardant or water delivery and a propane weed burner for burning out and backfiring. Over 79 machine days and 1250 hours of actual use were compiled in 1971 with no down time. It proved less damaging to surface environment than crawler tractors. Fire suppression performance was outstanding. —INT(600).

153. Fire management prescriptions for a 100-square mile study area in the White Cap and Bad Luck Drainages of the Selway-Bitterroot Wilderness were established and approved in 1972. These prescriptions were based on investigations of wildland fuels, plant communities, landforms, and fire spread and intensity potentials. A lightning-caused fire burned for 43 days in August and September of 1973 in the ponderosa pine savanna, shrubfield, and ponderosa pine/Douglas-fir zones of the study area. Among the observed effects of this fire was a significant reduction in all sizes of fuels except the surface litter, which in some cases increased due to fresh needle fall from scorched lower branches of trees in the burned area. The results of this work will be valuable toward applying this concept to other wilderness areas in the West. —INT(593).

Forest fire science

154. Basic information is needed to more adequately model and predict forest fire behavior. In response to this need, research efforts indicate that buoyancy production rates for a pure heat source and for a fire heat source of burning woody fuels show that fire may be regarded as a pure source yielding heated air rather than heated combustion products. This finding simplifies development of scaling laws for modeling fires. Ultimately, we will be better able to predict fire behavior. —SE(605).

155. The burning of cellulosic materials, such as forest fuels, is preceded by very complex chemical reactions. The key to better understanding and control of fire depends upon obtaining more fundamental information about these reactions. Significant progress has been made in recent years, especially on the effects of heating rate and chemical additives. The improvement of fire control methods and techniques and the development of better fire retardant chemicals are the ultimate outcome of this work. —PSW(602,603,611).

156. The interaction of fire and local environment gives rise to the complex problems of fire behavior. A model was developed for the purpose of predicting the fire-induced effects upon the winds and temperature fields which are a result of the interaction of fire and local environment. The model employs local ambient winds as initial conditions and the flame front temperature as a boundary condition to solve a set of turbulence model equations making use of a "stream function vorticity algorithm." The outputs are the fire induced winds and temperature departure from the fire front. This model will ultimately be a useful tool for forest fire and wildland management, planning, forecasting, and decisionmaking with regard to initial attack and firefighting strategies. —PSW(613).

157. Wind, temperature, and humidity in the atmospheric boundary layer strongly affect the way a fire behaves. The rates of spread and fire intensity are shown by the fire's temperature history. Experimentally, fires were found to add heat to the air flows in ways described by modern turbulence theory. These results help in developing models of fire behavior in southern California chaparral fuels. —PSW(608).

158. An important factor in the flammability of forest and chaparral fuels is the fuel moisture. This is obtained by weighing the moist fuel, then drying and reweighing it. Research has shown that the microwave oven can be used to dry fuel. It is a fast, accurate, safe, and simple method, which can be used any place where there is a source of electrical power. This system provided the operational fire manager with fast, accurate fuel moisture information, which, for practical purposes, was previously unavailable. —PSW(609,610).

159. The planar intersect method is the most commonly used method of estimating slash fuel loadings in the U.S., Canada, and Australia, but it has two inherent biases. The biases were theoretically eliminated by using quadratic mean diameter of particles and average secants for particle angles. Mean diameter and secants suitable for 11 types of conifer and hardwood slash and naturally fallen debris were computed so the intersect method may be used without bias throughout the northern U.S. —INT(604).

160. There is a need to validate fire fuel models and rate-of-spread models developed through fire research efforts to date. Study results indicate that, using the current grass fuel model, Rothermel's mathematical fire spread model overestimates the rate-of-spread of low to medium intensity fires. By adjusting the moisture of extinction values and fuel bed depth, close agreement can be obtained between measured and observed spread rates. Additional findings indicate that the fire spread rate model is basically sound, but additional field verification studies are necessary in order to "fine tune" prediction equations for spread rates as well as the fuel model inputs. Improved capability to predict fire spread will enhance our ability to economically manage and control fire. —PNW(612).

161. Recent advances in the understanding of lightning and its effects include: 1) New evidence that a specific type of electrical discharge causes most lightning fires in forests; 2) a new hypothesis on how lightning ignites forest fuels; and 3) a fuller recognition that lightning—in addition to causing wildland fire--produces mechanical and physiological effects that are exploited by wind, insects, and diseases. These conclusions, together with the capability of lightning to render nitrogen from the atmosphere, qualify it as a powerful agent of change in forest ecosystems. —INT(615).

Improving Insect and Disease Control

Detection and evaluation

162. Grand fir is an important component of the mixed-conifer forests in the Blue Mountains of Washington and Oregon, but management of this tree has been difficult because of excessive defect. Timber cruisers were handicapped because accurate methods for making defect estimation in standing trees were not available. After dissecting 1,090 trees on 65 plots in the area, researchers have developed two methods for estimating internal defect. If these methods are adopted, the management of grand fir will be improved greatly. —PNW(435).

163. Black walnut is one of the most desirable timber species in the United States, but attempts to grow this tree in plantations are not always successful. A stem-girdling canker of young trees has been found in plantations in the Central States. Canker initiation and development are postulated to result from fungal invasion of the stem following injury by insects. Plantation managers in the Central States can minimize losses by controlling insect-breeding sites and practicing adequate stand maintenance. —NC(437).

164. Radiography is being used as a means of nondestructive testing in forestry and related fields, but its value in work with trees, seeds, and the organisms that affect them has not been realized. A simple system has been developed to explain the use of sensitometry for film selection and optimum film performance. Use of this system will enable scientists to obtain greater benefits from the use of sensitometry in soft-tissue radiography. —NE(436).

165. Decay in living trees and wood-in-use most often becomes viable only after most of the internal wood fiber at one or more points has been destroyed. To permit earlier recognition of internal defect, an instrument has been developed that will detect decayed or discolored tissues. The instrument consists of a long, slender probe that measures the difference in electrical resistance of wood fibers through a small-diameter hole bored for that purpose. With proper calibration, this instrument could be used anywhere by foresters, pathologists, and commercial tree management officials to determine the extent of degradation in trees, poles, pilings, and other wood products. —NE(438,441,442).

166. The most serious disease of forest trees in the southern United States is fusiform rust. A recent forest survey showed that 800 million slash and loblolly pines have stem infections with highest percentages in an area across central Georgia. Annual stumpage loss to infections on living trees exclusive of mortality was estimated at 28 million dollars. Forest managers will use these data to evaluate management options for forest lands in the South. —SE(439).

167. In Mississippi, a serious canker disease has been found on Formosan sweetgum, a tree introduced from Asia. The fungus associated with this disease is closely related to the chestnut blight fungus that destroyed the American chestnut early in this century. The chestnut blight fungus was introduced from Asia and the infection of an introduced Asiatic tree with a native American fungus suggests the possibility of a reciprocal epidemic in Asia should our Formosan sweetgum pathogen be introduced there. —SO(444).

168. Phloem necrosis, a lethal disease of elms, is getting renewed attention after two decades of relative obscurity. This disease, which has recently been observed in New York, Pennsylvania, and New Jersey, may be controllable by proper use of an antibiotic. Information on diagnostic features has been assembled. Arborists, plant pathologists, and entomologists in the West, South, and Northeast will be able to recognize diseased trees and make appropriate management adjustments. —SO(443).

169. The European pine shoot moth is most damaging in ornamental and plantation pines. In the Pacific Northwest, methods have been developed for detection trapping of this insect by using a synthetic sex attractant. Information is provided on dosage-response, controlled-release formulation, distance-response, trap placement, and seasonal timing. Entomologists in the northeastern, northern, and northwestern parts of the United States will be able to monitor European pine shoot moth populations more accurately with this technique. —PNW(315).

170. Ground checking is necessary to verify insect mortality observations on aerial photographs. A computer-aided sampling technique was combined with aerial photography to overcome this problem in a California pine stand infested with western pine beetle. The spatial distribution of dead trees was displayed on a map of tree-mortality spots visible on photographs, and a stratification scheme was devised to randomly select the spots for ground checking. Further use of this technique will increase the utility of aerial photographs and enable the land manager to assess and to adjust for insect-caused mortality more effectively. —PSW(317).

171. Wood-boring insects significantly reduce hardwood lumber grade yield and value in the eastern United States. An evaluation of oak-borer-caused losses in West Virginia, Ohio, and Kentucky showed that these pests reduce the value of red oak factory-grade lumber $24 per 1000 bd. ft. The total loss from wood borer damage in standing sawtimber in the three-

State area is estimated to be almost half a billion dollars. The magnitude of these losses emphasizes the need for controlling borer-caused defect in oak forests. —NE(318,319,342,345).

172. Faster and more accurate techniques are needed to replace routine dissection and microscopic examination for studying insects and assessing insect damage to tree seeds. Procedures have been developed to nondestructively examine southern pine seed with x-rays. This information will provide the basis for a more rapid and standardized examination of many forest tree seeds. —SE(320).

173. Coneworms cause a major loss of seed in southern pine seed orchards, but their impact is difficult to assess. In northern Florida, second-year cones infested early in the summer fall from the trees before harvest, thus precluding an accurate assessment of coneworm damage. A regression equation, compensating for this premature cone fall, has been developed to estimate the total coneworm damage. Entomologists and geneticists will now be able to better evaluate the impact of coneworms and the effectiveness of chemical control treatments. —SE(316).

Biology and understanding

174. Logging residues contribute to proper nutrient cycling, but they also may interfere with new growth and provide a habitat in which destructive insects and disease-causing fungi proliferate. Available information on forest residue deterioration was summarized and the research needed to learn better methods of inducing rapid decomposition has been identified. Foresters in the Pacific Northwest can now practice improved residue management. —PNW(445,449,483,484).

175. Wood-decay fungi have relatively nitrogen-rich vegetative mycelium, sporophores, and spores, but the source of this nitrogen has been questioned because heartwood, which is the portion of a tree most commonly decayed has a low nitrogen concentration. Bacteria from white fir in southwest Oregon were found to fix atmospheric nitrogen. These bacteria also were associated with the major decay fungi of white fir, and their high concentration indicates that they have an important role in supplying nitrogen to these fungi. Knowledge of this association will aid forest pathologists and physiologists everywhere who are investigating the basic principles governing cause and development of decay in trees. —PNW(446).

176. The needle-cast fungus, *Lophodermella morbida*, has been destructively epidemic in pine plantations in California and Oregon. Recent investigations suggest this is probably a native fungus catapulted to prominence in populations of a very susceptible host growing on unfavorable sites where climatic conditions favor disease spread. Recommendations have been developed for avoiding losses, and forest managers in that area will be able to minimize the impact from *L. morbida* by following these recommendations. —PNW(460).

177. *Phellinus* (*Poria*) *weirii* causes a serious root disease of conifers in western North America and measures to reduce fungus survival in dead root systems have not been developed. When urea was added at 600 0N/acre, fungus survival in buried wood was significantly reduced. This knowledge may lead to a treatment for reducing *P. weirii* root rot damage in the West. —PNW(482).

178. Pacific madrone cohabits with Douglas-fir in many places along the West Coast and the two trees often compete for soil nutrients and moisture because of a shared fungal absorbing system. Several symbiotic fungi form mycorrhizal associations with the two trees, and one of these fungi has been identified and described. This new knowledge will permit research workers in the Pacific Northwest to better understand the interactions between these trees and to plan new studies with the objective of developing improved forest management recommendations. —PNW(520).

179. Many of the mycorrhizal fungi which form close association with plant roots have been neglected because few researchers know how to find and identify them. The ecology and methods of working with subterranean-fruiting (hypogeous) fungi are now presented in handbook format. Researchers and mycologists throughout the country can include these important root symbionts in recommendations for enhancing tree survival and growth. —PNW(434).

180. Mycorrhizal fungi are essential to nutrition of most green plants but are little known outside North Temperate areas. On invitation of Mexican scientists, an exploration of Mexican subterranean mycorrhizal fungi was initiated in 1972. About 250 collections were obtained from tropical to subalpine forests. Early analyses of specimens indicate that many species formerly thought to occur only in the U.S. extend well into the tropics. These species provide a broad range of ecotypes for use as mycorrhizal innoculum in nurseries throughout the country. —PNW(511).

181. Dwarf mistletoes parasitize many coniferous species in the western United States, but efforts to do basic research that would provide information upon which to base control recommendations have been hampered because a method for producing infected seedlings on a continuous basis has not been available. A technique has now been developed which permits year-round production of uniform, infected seedlings. This methodology will enable researchers in the North and West to intensify dwarf mistletoe investigations. —PNW(468).

182. Nearly 95 percent of the world's plant species, including many forest trees and shrubs, are nutritionally dependent on mycorrhizal fungi in the family Endogonaceae, but these fungi are little understood, in part, because of difficult taxonomic problems. All the known species in the Pacific Northwest are now described and classified. For the first time, plant scientists in that area can identify the Endogonacae that are involved in root symbiosis with higher plants. —PNW(454).

183. Prevalence of root rotting fungi may be influenced by the above-ground flora because higher vegetation affects numbers and kinds of soil microorganisms by affecting soil moisture, temperature, deposition of litter and production of root exudates or leachates. Soils under alder stands in Oregon had more species of microorganisms than either those under conifer stands or those under mixed alder-conifer stands. If some of the numerous organisms in soils under alder stands inhibit conifer root pathogens, forest managers in the Pacific Northwest should consider rotation of alder and conifer to improve conifer growth and vigor. —PNW(475,519).

184. Approximately 175,000 acres of Hawaiian ohia lehua forests are in various stages of decline. *Phytophthora cinnamomi* has been isolated from soil and from ohia lehua roots in the area. Although different soil types and ages of lava flow were involved, rainfall is adequate to perpetuate the fungus within the decline zone. The fungus is widespread in wildlands including forests on the island of Hawaii, and forest managers will have to select species and plan reforestation carefully should the damage be attributed to this fungus. —PNW(448).

185. The occurrence of European mistletoe, *Viscum album*, in California is the only known case of introduction, establishment, and spread of any mistletoe from one continent to another. Since its introduction in the early 1900's, it has infested an area north of San Francisco of about 16 square

miles, and has been found on 21 different native and introduced tree species. In California, *V. album* is not considered a serious economic problem because of its slow rate of spread and because the plant does only limited damage to commercial orchards. Foresters need not be concerned unless a virulent hybrid develops or the climate changes. —PSW(498).

186. Mistletoes parasitize woody plants throughout the world causing malformation, growth reduction, and mortality. The species of *Phoradendron* that parasitizes hardwood trees in the United States, their distribution, and methods for control have been popularly described. Mistletoes that infect woody plants growing outside their natural range or in ornamental plantings have been listed by species and host. Foresters, arborists, and individuals responsible for shade and ornamental hardwood trees can refer to this information which details occurrence and control of mistletoes in their plantings. —PSW(461,497).

187. Black stain root disease and the losses caused by it are becoming more important in second-growth Douglas-fir stands along the Pacific Coast. Current knowledge about this disease and some silvicultural treatments to alleviate its damage are described. The management options and silvicultural treatments will benefit forest land managers in the area. —PSW(510).

188. Development of methods for control of white pine blister rust has been impeded by lack of understanding of the biological interaction between pathogen and host. Bark from diseased western white pine has been found to have significantly less pectin but more materials extractable in petroleum ether and ethanol than bark from uninfected trees. In pure culture, enzyme (ribonuclease) activity increases with increasing age and new forms develop that possess unusual catalytic properties. Such results suggest that the host plays a major role in disease development. This information will permit research workers to test new techniques in the search for an acceptable strategy for controlling white pine blister rust throughout the range of five-needle pines. —INT(458,515).

189. Study of the nutrition of the white pine blister rust fungus has been hampered by inability to grow the fungus on artificial media. A defined nutrient medium was developed that supported fungal growth and upon which the fungus subsequently developed immature spores, re-infected germ-free host tissue, invaded leaves of the alternate host, and produced spores. This knowledge will permit researchers to explore new avenues for control of white pine blister rust. —INT(459).

190. Some western white pines resist infection by the white pine blister rust fungus, but the mechanism for this resistance is not understood. In culture, host tissues and fungus interact prior to, during, and after invasion. The exact host-fungus appearances at each stage of invasion of both tissue culture and tree bark were determined by electron microscopy. Appearances suggest that the fungus feeds primarily when in contact with host cell walls, and that the fungus might be controlled in spaces of bark tissues. This information will assist researchers who are investigating the biology and attempting to develop materials for control of white pine blister rust. —INT(494,495,514).

191. Pole blight is a very serious killing disease of western white pine that appears related to rootlet deterioration and consequent lack of water available to the tree. The symptoms of pole blight did not develop on 85-year-old trees deprived of some or all precipitation for 13 years. Upon excavation, vertical roots were found to have extended into water layers deep in the soil before the study was begun. The forest manager cannot predict occurrence of pole blight on the basis of low precipitation alone, and future researchers should investigate the relative capabilities of conifer root systems to competitively obtain nutrients. —INT(473,474).

192. Dwarf mistletoe does not occur in the heart of the Douglas-fir range in western Washington and Oregon although common to the species elsewhere. While the parasite now appears to be invading the area, it is believed to have been excluded in the past by individual host and parasite requirements, climate, physiography, forest ecology, and succession. Although all facets of the interrelationship are not known, land planners and managers should always consider the possibility that a substantial change or alteration in the forests may induce a massive dwarf mistletoe invasion of this important timber producing area. —INT(518).

193. Information on seed viability, germinability, dormancy, and longevity was unknown for some species of dwarf mistletoes, which are a major cause of reduced growth and death of western American conifers. A brief period of physiological dormancy is indicated for four taxa tested, but no particular unusual conditions are required for germination. Optimum storage temperature is near 0°C under low relative humidity. Inoculations with dwarf mistletoe seeds would be considerably enhanced if collection, storage, and germination treatment guides established by this study are followed, and results from such tests would permit more effective recommendations for control of dwarf mistletoe in the Western United States. —INT(517).

194. Southwestern dwarf mistletoe (*Arceuthobium vaginatum*) is the most damaging disease of ponderosa pine in the southwestern United States and in parts of the central Rocky Mountains. The available information on host relationships, life cycle, ecology, damage and control recommendations for this serious pest have been summarized. This information will enable forest managers in the affected area to minimize dwarf mistletoe damage on their lands. —RM(476).

195. Dwarf mistletoes are insect-pollinated and at that stage in their life cycle they may be amenable to control. To better understand the pollination attraction mechanism, nectar produced by pistillate flowers was analyzed by thin-layer and gas-liquid chromatography and found to contain 58-92 percent sugars composed primarily of glucose, fructose, and sucrose. This high sugar content is probably a strong insect attractant and also may be a major factor contributing to the spread of this disease. If this relationship can be established, researchers will have additional information upon which to base control strategies for dwarf mistletoes of northern and western coniferous forests. —RM(450,455).

196. As containerized forest tree seedling production is increased, the diseases that reduce quality or kill plants become more important. The fungi and nematodes that cause damping-off, root rot, foliage diseases, and seedling blights have been identified. Conditions in seedling production facilities that promote disease development and controls for some developed diseases have been described along with possible causes and preventions for physiologic chlorosis or yellowing of containerized seedlings. Nurserymen throughout the United States will be able to use this information to identify and control new problems as they arise. —RM(490).

197. Large numbers of seedlings are produced in forest tree nurseries, but omnipresent diseases caused by fungi, bacteria, and nematodes reduce production unless constant vigilance is maintained and control actions employed. A recent publication with numerous illustrations describes 32 important nursery disease problems of forest trees in the United States. This in-

formation will assist nurserymen, foresters, extension pathologists, and others in identifying, evaluating and controlling the diseases encountered in forest nurseries. —RM(492,492).

198. Phomopsis blight, caused by *Phomopsis juniperovora*, is the most damaging disease of junipers in Great Plains nurseries. The fungus forms orange-red crystals in agar cultures and the main constituent of these crystals has been identified as a tetrahydroanthraquinone compound, altersolanol A. Whether this compound is involved in the infection process can now be investigated because it can readily be identified by spectroscopic methods. —RM(516).

199. The relatively low quality of sugar maple in the hardwood forests of Minnesota has not been explained and there is no known preventive for this condition. Annual cankers, which are common and increasing in number, apparently are not of pathogenic origin. Timber cruisers and mill operators in the State should be aware of these hidden defects and should assume that they probably will be more numerous in the future. —NC(466).

200. Several conifer foliage diseases have been disseminated widely in the Northern and Northeastern States by movement of infected seedlings from nurseries to plantation sites. Inadvertent shipment of diseased materials has often occurred because seedlings infected with some diseases are difficult to detect in the spring when most stock is lifted and shipped. Information has been developed to facilitate detection and control of some of these diseases. Nurserymen and plantation managers can minimize spread and practice control of foliage diseases in that area by following recommended procedures. —NC(485).

201. Dwarf mistletoe causes a very serious killing disease of conifers but the method whereby new infection centers become established is unknown. Birds and other animals have been found to carry dwarf mistletoe seeds on feathers or fur and thus are believed capable of serving as vectors for this organism. Forest managers in the North and West should recognize the potential for establishment of dwarf mistletoe infection centers in healthy stands especially along the routes of migratory birds. —NC(465).

202. *Rhizosphaera* needlecast has been found for the first time in blue spruce Christmas tree plantations in the upper Midwest. Infected trees suffer defoliation and branch mortality beginning at the base of the tree and progressing upward. Fungicide treatments have been developed to control this problem. Nurserymen and plantation managers can limit losses in the affected area by following appropriate recommendations. —NC(486,571).

203. Changes in trees induced by disease or other factors can be measured by changes in enzyme activity. New or improved techniques have been developed to detect protease and dehydrogenases and to increase the length of time during which they can be studied after having been collected. Plant pathologists, biochemists, and geneticists in all regions now can work with these materials and may continue their experiments over longer periods of time with no significant loss of accuracy. —NC(456,499,500).

204. Brown spot needle disease causes damage to Scotch pine Christmas tree foliage. Through life history studies, the period of spore dissemination and infection has been documented and chemical and cultural control measures can now be timed so as to be most effective. By following recommended procedures, Christmas tree growers in the North Central States will be better able to limit damage in their plantations. —NC(509).

205. Insects or environmental stresses can defoliate hardwood trees, but even repeated defoliations are rarely the sole cause of tree mortality. Evidence obtained in the Northeast indicates that the root rotting fungus, *Armillaria mellea*, contributes to the death of defoliated sugar maple trees and that the ability of the fungus to infect was influenced by when and how often the trees were defoliated. Forest managers in that area can expect occurrence of *A. mellea* in stands that have been under stress and can deduce the previous occurrence of stress when mushrooms of this fungus are found. —NE(512,513).

206. Urban trees suffer diebacks and declines which are often initiated by environmental stresses. These stresses can result from air pollution, defoliation, addition of chemicals, and changes in moisture or temperature. Following the stress period, innocuous organisms may cause serious damage. A summary of various diagnostic and preventive techniques has been prepared to help city foresters and urban planners in the Midwest and Northeast to better manage urban trees. —NE(464).

207. Various injuries predispose trees to dieback and decline and to attack by biotic agents, but reasons for such predisposition are unclear. Starch levels in roots of sugar maples defoliated in Connecticut were lowered more than in roots of trees that were defoliated and girdled or those that were severed from the stump. It has been concluded that carbohydrates are moved upward in the phloem (and to a lesser extent in the xylem) of defoliated stems. Tree pathologists and physiologists now have additional information to help explain relationships between trees and various agents which adversely affect them. —NE(487,505).

208. In north central New York, white pines planted to reforest abandoned farms develop cankers if injured by ants, snow, or ice. A similar situation has developed in Maine where white pines have been planted as natural snow fences on farms along the interstate highway system. Snow and ice damage was greatest in rows oriented perpendicular to winter winds. Forest managers and land planners should avoid use of white pine for reforestation of open lands, natural fencerows, or shelterbelts in the extreme North. —NE(462,463).

209. Some of the materials present in the bark of trees affect the ability of fungi and insects to penetrate and establish themselves within. To determine the role of some of these materials in excluding insects and fungi, the concentration and seasonal variability of phenol-bound sugars were examined in five species of deciduous trees of eastern forests. It was concluded that these sugars do not change markedly with the season. Forest pathologists will use this knowledge in formulating new hypothesis for additional investigation of disease and insect problems. —NE(488,489).

210. The relative vigor or health of trees is thought to be best when starch content of roots is highest. However, starch content is difficult to determine even in the laboratory. A relatively simple method has been developed to enable determination of starch contents of roots in the field. Researchers and foresters can use this technique in working with oaks and sugar maples in the Northeast. —NE(477).

211. Pecan bunch is a widespread and serious disorder of pecan and native hickories that results in tree decline and reduced nut production in eight southern States. Although formerly assumed to be caused by a virus, recent research suggests that a mycoplasmalike organism is associated with diseased trees. This association suggests that mycoplasmas rather than viruses may cause many yellows-type diseases of forest trees and that these problems may be controllable by

proper use of tetracycline antibiotics. Forest managers in the South will benefit if a technique for controlling these diseases can be developed. —NE(503).

212. Prevention or control of wood decay in living trees is dependent upon developing a better understanding of the steps, processes, and microorganisms involved. Indications are that a regular succession of organisms is responsible for decaying wood, and if one could disrupt this succession, the process may be stopped. Also, it may be possible to prevent damage by introducing other organisms to exclude those that cause damage. Some evidence suggests a common mold fungus can exclude decay-fungi from becoming established in tree wounds for up to 1 year in the Northeast. More work must be done to clarify the principles related to wood decay and to develop practical control recommendations. —NE(496,504,506,507).

213. Concentrations of microelements that are present in wood inhibit the growth of some microorganisms while others are not affected. Five common wound-invading organisms isolated from discolored portions of northeastern hardwoods grew well in the presence of high concentrations of manganese, calcium, zinc, and iron. The ability to tolerate high mineral concentrations may enable these fungi to be aggressive wound-invaders while the growth of other, less tolerant, species is inhibited. Basic researchers dealing with the initiation and development of wood decay will use this information in developing new concepts and research proposals. —NE(508).

214. Mycorrhizae are symbiotic associations between plant roots and fungi that are essential to survival of many trees and shrubs on forest and urban sites. Among many benefits to the plant from such an association is protection from some disease-causing organisms. The various types of protection and the mechanisms involved have been reviewed. Foresters, nurserymen, and plant pathologists everywhere should be aware of the extent and limits inherent in this form of biological protection and be able to modify management practices according to existing conditions. —SE(447,478).

215. Production of containerized seedlings has uncovered many problems with tree roots and several of these involve establishment of mycorrhizal associations with various fungi. The subject of mycorrhiza has been reviewed and the relationship between production of container stock and mycorrhizal root systems considered. Nurserymen and land managers who are involved with containerized seedlings should be aware of the role of mycorrhizae in seedling production and establishment. —SE(479).

216. Identification of individual fungi that grow in association with tree roots has been very difficult. A new technique involving use of highly specific antibodies has been developed to differentiate various ectomycorrhizal fungi that occur on tree roots. Scientists and nurserymen throughout the country should be able to reliably differentiate preferred ectomycorrhizal fungi from wild types for better growth in nurseries and forests. —SE(502).

217. Fusiform rust currently causes serious damage to pines in the Southern United States. However, pine species native to the Western United States, such as ponderosa, Monterey, and Jeffrey, were found to be highly susceptible to fusiform rust in artificial inoculation studies. In addition, California black oak was susceptible and could serve as an alternate host. Because the natural ranges of these western pines and oak overlap, this rust might become established in the West if introduced into that area. Forest managers and nurserymen should screen stock imported from the South to prevent introducing fusiform rust into the Western United States. —SE(453).

218. Canker-rot fungi cause degrade and cull in southern hardwoods, especially red oaks. The fungi that cause damage are distinguished from numerous others that cause heartrot by their ability to kill the cambium and induce cankers. The cause, symptoms, hosts, and damage attributable to them have been described. Forest managers in the southern States now can take appropriate action to minimize losses caused by these fungi. —SO(480,481).

219. The search for organisms that might be useful in biologically controlling forest pathogens or biodegraders continues even though success in the past has been minimal. A fungus that apparently parasitizes sporophores of the lignicolous fungus, *Peniophora tamaricicola*, was recorded from Arizona. Parasitism was not proven, but the species was described as new and was named *Platygloea mycophila*. A determination that *P. mycophila* actually parasitizes its host would be justification for using this fungus in biocontrol tests. —FPL(452).

220. Decay fungi cause millions of dollars in losses in living trees, logs, and slash in American forests, and it is important that we know as accurately as possible the names of the organisms involved. Three new North American species in each of two genera, *Laeticorticium* and *Phanerochaete*, were described in detail from sporophores and cultures. Studies clearly indicated that *Laeticorticium could be separated into the two genera, 0I Dendrocorticium* and *Dentocorticium*. The worldwide species in the genus, *Tomentella*, were described in a single monograph. These results will aid mycologists and forest pathologists everywhere in the study of decay fungi. —FPL(451,470,471,472).

221. Analytical procedures must be used to distinguish between closely related living organisms that coexist in ecosystems. The chemical, syringaldazine, which had previously been noted to detect the enzyme, laccase, with great specificity in cultures of lignicolous fungi, was found to be satisfactory for testing sporophores and wood in the field. Methods to eliminate interference by two other enzymes, tyrosinase and peroxidase, were elaborated. A dark brown pigment that develops in sporophores of one wood-rotter after application of a base was also partially characterized chemically. Definitive tests for three enzymes can now be conducted by scientists and technicians at the site and time of collection anywhere in the world for more reliable definition of the fungi decaying wood and the action each takes. —FPL(457,467).

222. To predict outbreaks of the Douglas-fir tussock moth, it is necessary to study the outbreak cycle in its entirety. However, this is very difficult because infestations are rarely detected until populations have increased to damaging numbers. Data were collected annually (1967-1971) from an isolated population in a mixed conifer forest (Douglas-fir, white fir, ponderosa pine) in Arizona. The outbreak cycle was defined and correlation analysis showed that density of small larvae accounted for a large proportion of the annual change in population density. Local infestations developed largely from resident populations rather than from long-range spread. Entomologists in the West can predict more accurately the development of future outbreaks of tussock moth and make recommendations for control. —PNW(352).

223. Both potentially damaging and beneficial insects breed in forest residues and the question of whether these residues should be treated remains unresolved. A review of insects associated with forest residues shows that many treatments would reduce some insect pests but might also destroy certain

beneficial insects. Researchers must clarify the role of insects in forest residue management before treatment techniques can be developed. —PNW(363).

224. Christmas tree plantations often are fertilized to improve growth and color but the effect of this practice on insect populations was unknown. Seven-year old Douglas-fir in the Pacific Northwest had increased numbers of Cooley spruce gall aphid eggs and higher winter survival of aphids after nitrogen fertilization. However, 2 years after fertilization the aphid populations were essentially the same in treated and untreated trees. This indicates that Christmas tree growers can continue fertilization of Douglas-fir without concern about increasing aphid numbers. —PNW(362).

225. The Sitka spruce weevil attacks terminals of Sitka spruce and seriously affects growth and form of this tree along the coast of Oregon and Washington. Fifteen years of study on the susceptibility of 10 spruce species and hybrids to the weevil showed that Lutz spruce (a natural Sitka-white spruce hybrid from Alaska) grows well in Oregon and Washington and its susceptibility to weevil attack is about 1/10 that of Sitka spruce. Forest managers will be able to use Lutz spruce as a replacement for the heavily-weeviled Sitka spruce. —PNW(361).

226. Sampling populations of defoliating insects requires knowledge concerning leaf populations on host trees. Research in Oregon and Washington showed that total needle populations on young Douglas-firs can be estimated by regression analysis. It was also found that a life table model in the general format used by actuaries is a suitable format for evaluating needle occurrence, mortality, and age distribution. It is visualized that these techniques will be useful throughout the country for sampling leaf feeding insects and evaluating their impact. —PNW(359).

227. Previously undescribed organisms associated with important tree species should be described to aid future workers in identification and evaluation of the role of these organisms in the ecology of the tree. A new species of mite was found infesting the bark of grand fir in Oregon. The male, female, and deutonymph of this species was described and illustrated. This information adds to the knowledge of potential pests infesting grand fir. —PNW(360).

228. Correct identification of insect viruses is essential to properly evaluate and use these materials for control of insect pests. The approved general nomenclature for most insect viruses is listed. While some of these genera may also contain viruses of vertebrates, it is significant that the genus *Baculovirus* appears to have no association with vertebrate viruses. This is an important factor in evaluating the safety of these viruses as microbial control techniques, and entomologists throughout the country will benefit from this information in developing microbial control techniques. —PNW(391).

229. The spruce budworm, *Choristoneura* species, represents the most damaging group of coniferous forest defoliators in North America. Field screening techniques conducted in British Columbia and Oregon, established (E)-11-tetradecenyl acetate, and (E)-11-tetradecenal as the principal sex pheromone components for *C. viridis* and *C. biennis*, respectively. These findings are of major importance in the development of detection survey techniques and environmentally safe control procedures for these budworms. —PNW(377).

230. Understanding the biology of parasites is important to being able to predict population changes of important forest pests. Reproduction of two important parasites of Pacific Northwest forest insects was severely impaired at 100 percent R.H. but was quickly restored when they were transferred to 62 percent relative humidity. This suggests extended periods of high humidity may contribute to temporary reduction of parasite numbers and permit an expansion of the pest population. This information will be useful in developing models to predict trends in forest pest populations throughout the country. —PNW(375).

231. Although parasites have a significant role in regulating populations of the large aspen tortrix, the natural parasites of this important aspen insect are relatively unknown. In Alaska, 24 species of parasites have now been described and information on their biologies is provided. This reference material will enable entomologists and others to assess the role of these parasites in the dynamics of tortrix populations in that area. —PNW(390).

232. The natural enemies of larch casebearer, which causes serious growth reduction in western larch, do not exist in the Western United States where this insect was first found in 1957. *Chrysocharis laricinellae*, an important European parasite of this insect which has successfully controlled larch casebearer in the Eastern United States, has been introduced into the West. An established population of the parasite now has been reported in Idaho. If *C. laricinellae* continues to spread, it may provide forest managers with an effective control for larch casebearer in the Pacific Northwest. —PNW(376).

233. The larch casebearer, which causes serious growth reduction in western larch, is difficult to control because it is not exposed to biological or chemical control agents in its leaf mining stage. Studies in southeastern Washington showed that most larvae reached the more vulnerable casebearing stage between September 11 and October 25 and thus fall releases of parasites to control casebearing larvae should be delayed until after mid-September. This information will help forest managers in the Pacific Northwest select control options for the larch casebearer more effectively. —PNW(374).

234. The European pine shoot moth is an introduced forest pest which is becoming increasingly important to pine nurseries, plantations, and ornamental trees in the Pacific Northwest. Opportunity for development of survey and control methods is increased by chemical identification of the sex pheromone of this insect as (E)-9-dodecenyl acetate. Availability of this pheromone is expected to be very helpful in permitting entomologists and others to conduct surveys and develop control programs throughout the Northern Untied States where this insect occurs. —PNW(380).

235. Locating pertinent literature is critical to identifying forest insect pests. The three volumes of the catalog for the Hymenoptera of America north of Mexico are very important bibliographic and systematic sources on hymenopterous insects, but the third volume, or 2nd supplement, of the catalog had no host index. A host index has now been prepared. Citations include both plant and animal host associations and the pages where they can be found. This index should greatly facilitate the identification of parasitic Hymenoptera and sawflies throughout the Nation. —PNW(389).

236. Study of defoliating insects in both interior and southeastern Alaska revealed an apparently undescribed insect parasite in the genus *Pygocryptus* , and others were found by examining specimens in private, university, national, and foreign collections. Taxonomic study yeilded two previously described holarctic species, four new species, and three new subspecies. Diagnositic keys and descriptions of the new species and subspecies are presented. This work may aid in future population and biological control studies of defoliating insects in Alaska. —PNW(388).

237. Investigation of the effect of sex attractants on insect behavior is dependent upon a full understanding of the basis and nature of odor response in insects. During the winter, both sexes of the beetle *Ips pini* showed a marked decline in respiration and in the response to both male frass and standard extracts of frass which contain the attractant. The results indicate a physiological change in overwintering beetles that may be a form of hibernation. This research provides the information needed by researchers in the North and West to standardize the assays used in the chemical identification of *Ips pini* attractants. —PSW(326).

238. A method must be devised for manufacturing the materials which affect behavior before insect populations can be managed with an insect-produced attractant. Part of the synthesis of brevicomin, the aggregating attractant of the western pine beetle, has been accomplished. This brings us one step closer to a practical control method for western pine beetle in California, Oregon, and Washington. —PSW(349).

239. Identification of pathological factors that predispose white fir to bark beetle attack is prerequisite to developing a risk rating system for selective cutting. Measurement of xylem sap tension in California white fir showed that heavy dwarf mistletoe infections increased moisture stress in upper boles and this condition was associated with high incidence of fir engraver beetles. White firs with dwarf mistletoe infections must be considered high risk, and forest managers should have them removed from the stand to prevent a buildup in fir engraver population. —PSW(340).

240. *Ips paraconfusus* is a serious pest of western pines when large populations build up in logging slash. Control procedures for this insect are lacking although work with sex lures shows promise. One of the compounds of the aggregation pheromone complex may be produced by a bacteria, *Bacillus cereus*, in the gut of the insect. This discovery opens new avenues to manipulating populations of bark beetles throughout the country. —PSW(327).

241. The mountain pine beetle causes high mortality to several species of pine in the western United States. A competing risks analysis has been used to evaluate the importance of various mortality factors on mountain pine beetle populations. This technique may be useful in predicting population trends of the mountain pine beetle and in indicating factors which might be manipulated to effect control. —INT(332,333).

242. Radiography has been used to sample populations of the western and southern pine bark beetles, but has not been tested on mountain pine beetle in lodgepole pine. In a Wyoming test to determine characteristics of mountain pine beetle populations, radiography and the standard bark removal technique gave comparable estimates of live beetle numbers. However, radiography is more costly, and the causes of beetle mortality usually cannot be determined. In addition, beetle populations in radiographed areas were adversely affected, probably because of drying of wood and bark, which resulted in erroneous estimates, of brood survival and distorted sex ratios. For those reasons, the radiographic method is not recommended for sampling mountain pine beetle populations. —INT(322).

243. Little is known about the biology of *Pityophthorus confertus*, a bark beetle which commonly infests decadent western pines and which occasionally causes mortality in healthy ponderosa pine. Infested billets of lodgepole pine from Idaho were brought to the laboratory to study brood development; information obtained will prove very useful in future population and control studies of this insect. —INT(321).

244. The white fir needle miner has caused serious defoliation and mortality of white fir in the Southwest. Descriptions of this insect and its life history and habits are assembled. Possible control strategies are discussed. With this information, forest managers in the West will be able to recognize and evaluate control options for this insect. —INT(392).

245. Little detail is known of the life history and habits of the roundheaded pine beetle, an important pest of ponderosa pine in the Southwest. Field studies in New Mexico have now documented the periods of adult beetle emergence and attack, and of brood development. This information will be useful to researchers and field workers alike in enabling them to better understand the ecology of the roundheaded pine beetle in Southwestern forests. —RM(350).

246. Lodgepole terminal weevil is common in interior forests in the Central Rocky Mountain and Intermountain areas. Sometimes its impact on infested stands causes concern to land managers. An analysis of situations in Colorado and Idaho showed that even where heavy infestations occur, long-term effects are not generally expected to be severe if the forest is managed for production of poles or sawlogs. Even light infestations would hinder production of quality Christams trees. This information should better enable managers to assess the importance of infestations occurring on their lands in terms of resource management objectives. —RM(387).

247. The impact of roundheaded pine beetle outbreaks on ponderosa pine stands in the Southwest has not been well understood. Data are now available on changes in stand density, species composition, tree size, and related factors following a beetle outbreak in south-central New Mexico. Land managers will use this information to make better decisions about what action to take, if any, when an outbreak occurs. —RM(386).

248. Population studies of the southwestern pine tip moth in Arizona required estimates of fecundity. A good correlation was found between pupal size and potential number of eggs. This information, combined with knowledge of other factors affecting egg-laying success, can be used to estimate fecundity, an important factor determining population trends. —RM(347).

249. Ponderosa pine trees successfully and unsuccessfully attacked by mountain pine beetle have several symptoms in common, so that diagnosis is not always easy. Guidelines now available will enable field workers to correctly distinguish nearly all successfully attacked trees. This will prevent removal of uninfested trees and make control operations more efficient. —RM(356).

250. Temperature is a major physical factor affecting bark beetles, but often the parameters for activity and development are unknown. In laboratory studies in Colorado, mountain pine beetles attacked logs, mated, and constructed egg galleries at 4.4°C, but no eggs were deposited in 6 weeks. Activity of adults and growth rate of larvae increased with increase in temperature. Knowledge of responses at the lower thresholds of activity is important to applied work leading to better control methods. —RM(355).

251. Survey methods for spring cankerworm egg masses are needed to predict defoliation and the need for control in Great Plains shelterbelts. The moths commonly deposit inconspicuous egg masses in crevices on the branches or trunks of Siberian elm trees. In field studies in North Dakota, egg masses were found also in old pupal cases of *Rogas*, a parasite of cankerworm, and in bark lesions caused by several diseases attacking host trees. Knowledge of these exposed oviposition sites will make it easier to make egg counts when cankerworm populations are at a low level. —RM(384).

252. The spring cankerworm is an important defoliator of Great Plains shelterbelts. Sometimes epidemic populations of cankerworms remain high even when all foliage on the host trees has been consumed before the larvae completed their development. Observations in North Dakota indicated that larvae dropped from the trees, fed on flax in adjacent fields, and continued their development into the pupal stage. Survival of the insect on unusual host plants may explain maintenance of high population levels of spring cankerworms. —RM(385).

253. The pinyon needle scale is a native sapsucking insect of the Southwest that occurs primarily on single-leaf pinyon. Information on its life history, distribution, ecological relationships, and control has been summarized. This information will enable forest managers in the Southwestern States to identify and control pinyon needle scale on their lands. —RM(357).

254. Spiders prey on insects, and documented records describing different predators and prey are helpful in delineating the ecologies of both groups. Crab spiders were found feeding on two genera of scarab beetles resting on pine trees in Arizona. These new records of prey, spider-habitat associations, and predators of scarab beetles extend our knowledge of relationships in forest ecosystems. —RM(348).

255. Little information has been available about the long-term effects of spruce beetle outbreaks, many of which seemed devastating at the time. Current stand conditions in western Colorado were evaluated 15, 25, 50, and 100 years after spruce beetle outbreaks had occurred. In general, adequate regeneration had resulted except in areas that had been heavily salvage-logged. Species composition was altered in favor of fir, which is expected to persist for many years, but eventually be overtaken by spruce. Land managers facing spruce beetle losses now have some insight into what long-term effects are likely from the outbreak. —RM(378).

256. Nematodes are recognized as important factors in bark beetle ecology, but information about them has been scattered, scanty, and generally difficult to obtain. A monograph is now available summarizing the current state of knowledge about these organisms and describing 32 parasites and 112 associates, many new to science Bark beetle specialists now have at hand a comprehensive and up-to-date review of this important group. —RM(353).

257. Nonpesticidal control techniques are desirable to minimize damage by the Saratoga spittlebug in red pine plantations. The most critical stage in the spittlebug's life cycle is when it hatches from the eggs that are on pine buds, searches out suitable host plants, on the forest floor, and covers itself with masses of spittle before it starves, dessicates, or is captured by predators. Normally 85 percent emerge between 0700 and 1100 hours; peak emergence is between 0800-0900 hours. Emergence is somewhat prolonged on cool, cloudy, or misty days. This information, plus other biological data, is necessary to develop pest management techniques for this important Lake States conifer plantation pest. —NC(395).

259. Adult jack pine tip beetles injure jack pine shoots and may deform trees in the Lake States. A wasp-like parasite causes significant beetle mortality during the second stage of larval development. This parasite was the only major mortality-causing factor and was responsible for 15 to 40 percent of the beetles' total mortality. The importance of the parasite suggests further study to determine its effectiveness as a regulator of jack pine tip beetle populations and damage. —NC(343).

260. A mixed larch provenance planting in Michigan was damaged by a little-known larch moth. The moth damaged shoot tips of eastern larch and several varieties of Japanese larch. Early larvae are leaf miners; older larvae are free feeders. Two generations per year occur in Michigan. Sufficient information is now available to test chemical suppressive techniques on this insect. —NC(366).

261. One potential method of minimizing damage to red pine plantations by the Saratoga spittlebug is to significantly reduce the growth of sweet fern, an alternate host of the spittlebug. A new species of moth whose larvae feeds on sweet fern has been described and studied. The moth has one generation per year and locally may severely damage sweet fern. Although this moth is common, it does not exist in numbers sufficient to significantly reduce the growth of sweet fern. —NC(393).

262. One potential method of minimizing damage to red pine plantations by the Saratoga spittlebug is to significantly reduce the growth of sweet fern, an alternate host of the spittlebug. Moth eggs were collected from sweet fern and the resulting larvae were reared and studied in the laboratory. This basic study is a necessary preliminary to assess the potential of biological control of sweet fern. —NC(394).

263. Population studies of the forest tent caterpillar require the ability to identify the sexes from as many life stages as possible. Previously, sex identification was only possible by examining the moths' antennae. Now, the position and size of the pupal genital opening is known to be a dependable diagnostic character. Entomologists concerned with population changes of this insect and other moths will find this technique useful. —NC(367).

264. If birds are to be considered an important predator of the jack pine budworm, they must be able to regulate their predation in response to variations in prey abundance. Predation by three common summer resident birds—black-capped chickadee, brown-headed cowbird, and chipping sparrow--was studied in response to ninefold variations in budworm populations. Bird predation showed little or no change over the wide range of budworm intensities. Therefore, bird predation probably will not be an important factor regulating jack pine budworm abundance, unless budworm densities are at low or endemic levels. —NC(354).

265. Moths of the family Tortricidae are a destructive but taxonomically confused group. The nomenclature of one group of these moths has been significantly simplified and one new species has been described. One moth species was found to vary significantly in size with elevation of capture- increased size coinciding with increased elevation. The updated and simplified nomenclature will greatly benefit all researchers working with this economically important group of insects. —NC(358).

266. The gypsy moth is one of the most destructive pests of forest, shade and orchard trees in the Northeastern United States. Analysis of data which was accumulated for 20 years in New England confirms that defoliation is most likely to occur in stands which have more than one-half of the overstory composed of oaks, gray and paper birch, or aspen. However, egg mass density is not related to overstory composition. This knowledge is essential to developing a rational approach to management policies that will prevent outbreaks of the gypsy moth. —NE(328,329).

267. Forecasting gypsy moth defoliation is difficult because insect density does not necessarily reflect amount of subsequent defoliation. A multiple-regression model developed from Massachusetts data reflects statistically significant correlations between defoliation by the gypsy moth and a series of biotic and physical variables. The results suggest current

criteria for control may lead to treatment of populations that would have caused little defoliation if left untreated. Those responsible for managing gypsy moth populations should evaluate their criteria for control action in light of this new information. —NE(330).

268. The ability to predict airborne spread of young larvae from parent population centers is essential to developing predictive capability for outbreaks of gypsy moths. A mathematical model was developed that predicts larval dispersal and identifies critical biological and physical factors that affect dispersal capability. Field verification of this model will provide a means for improving ability to predict gypsy moth spread in the Northeast. —NE(351).

269. Prior to developing the nucleopolyhedrosis virus (NPV) of the gypsy moth for control of this destructive defoliator on northeastern hardwoods, it was necessary to identify the most virulent strain available from many geographical sources. The most promising NPV's available were assayed and the strain with most virulence was identified. This strain is now being developed and tested for use in a gypsy moth management system. If effective, this will be a welcome addition to the techniques now available for gypsy moth control in the Northeast. —NE(372).

270. During a disease diagnosis study, it became necessary to develop a dissecting dish that could be sterilized and reused. Such a dish was prepared using a silicone encapsulant. Because the silicone can be autoclaved and will remain rubbery from 65°C to 250°C, it can be reused many times for pathological studies. This dish will have wide application when dissection of small animals is necessary. —NE(368).

271. Regression analysis, a commonly used analytical method for examining variables in a data set, can be very expensive if the number of variables is large. A method was developed which examines all possible regressions with a minimum of arithmetic and shows which subsets of variables are most important without examining all subsets. This method has wide application in research and it is being incorporated into the widely used biomedical package of statistical computer programs. —NE(341).

272. Dutch elm disease has spread throughout much of the United States since it was first introduced here in 1930, and during that time considerable effort has been expended to develop techniques for reducing the mortality caused by this fungus. Techniques now being tested include various procedures for limiting the population of the beetles which spread the fungus from diseased to healthy trees. If these procedures prove to be effective and become operational, they will have widespread application throughout the country for control of this disease. —NE(324,325,412,413,418).

273. For management of insect populations by sterilization techniques we need to determine the ratio of sterile to fertile males required to cause population decrease. A previously developed population model was examined to mathematically demonstrate the parameters necessary for the population to become extinct. This research will have national application in the development of those insect control procedures which utilize the sterilization technique. —NE(383).

274. Although insects seriously damage cones and seeds in southern pine seed orchards, we do not know what insects are most damaging to specific hosts at specific periods of conelet development. First-year flower and conelet losses, which accounted for the greatest reduction in seed yields, were due to seedbug and loopers on loblolly pine and seedbugs and tip moths on shortleaf pine. Major causes of second-year cone losses were coneworms, midges, and pineshoot borers. These findings will permit the establishment of meaningful priorities for future research and the development of control methods to minimize future losses. —SE(336).

275. Seedbugs are known to reduce seed production in southern pine seed orchards, but the nature of conelet damage was unknown. Second-instar nymphs caused 100 percent conelet abortion when confined to shortleaf pine conelets in a Georgia seed orchard for 4 days. Feeding was confined almost exclusively to the cytoplasm of nucellar tissue in developing seeds or ovules. This knowledge will be used to more effectively time chemical control applications and to develop systemic insecticides which should minimize seedbug damage in southern pine seed orchards. —SE(335).

276. The decline of seed yields in Southeast pine seed orchards has perplexed orchard managers for several years. Caging experiments and work with radiographs has demonstrated that seedbugs are responsible for much of the damage. Protected loblolly pine cones yielded 2.5 times as many filled seed as did cones exposed to natural bug populations and shortleaf pine cones yielded 12 times as many full seed as did uncaged ones. Seed orchard managers and entomologists will use this knowledge to develop control techniques for these insects. —SE(334).

277. Germination of slash pine seed harvested from some southern seed orchards is much lower than that harvested from the wild. Radiographic and microscopic examination of slash pine seed showed that many which appeared full by standard cracking procedures were actually seedbug damaged. Those seed lots in which extensive molding occurred during germination tests possessed greater numbers of seedbug-damaged seed. These observations implicate seedbugs as the major cause of the decreased germination and associated moldy condition of slash pine seed, and provide more evidence of the need for controlling seedbugs in southern forest tree seed orchards. —SE(373).

278. Coneworms drastically reduce yield of pine seed in southern seed orchards, and effective alternatives for control are needed. In a Florida study, larval feeding was stimulated by acetone extracts of slash pine cones and recombined fractions of the extracts. Stimulation also was induced by sugars from slash pine cones. Researchers can use this information to develop techniques using baits and repellents to control coneworms. —SE(337).

279. The fall cankerworm, which commonly defoliates maples, oaks, and hickories over extensive areas in the southern Appalachians, could not be reared in the laboratory to provide a supply of eggs to study an important egg parasite, *Telenomus alsophilae*. A successful method of rearing successive generations of fall cankerworm on cut foliage has been developed. When fully developed, this rearing method should supply ample fall cankerworms for biological studies of parasites. —SE(364).

280. The southern pine beetle is a very important killer of pine in Honduras, but its population trends cannot be predicted until insect associates, including parasites and predators, are determined. Thirty species of insect associates of the beetle were identified in Honduras. Nine genera were known biological control agents. Clerids and ostomatid beetles were in sufficient number to control bark beetles. This information will assist future workers in the study of population dynamics and biological control of the southern pine beetle in Honduras and possibly in the southern U.S. as well. —SE(331).

281. Studies of parasites to control the elm spanworm, an important defoliator of hardwoods in the southern Appalachians, depend on maintenance of a properly scheduled supply of

spanworm eggs in the laboratory. The first successful artificial diet for rearing elm spanworm through a complete generation has been developed. While modificiation of the diet and rearing technique is needed to increase survival, the method holds promise as a means of obtaining a continuous supply of the elm spanworm eggs for biological control research. —SE(338).

282. Mortality of pine seedlings on cutover lands is significantly increased by weevils, but information on weevil development was lacking. Tests have shown that the time required for development from egg to adult emergence ranges from 3 to 15 months, depending on date of oviposition and location. As a result, planting should be delayed one full year to avoid weevil damage on areas harvested in the southern Appalachians during the summer and also on areas harvested anytime after June in the Piedmont and Coastal Plains. Areas harvested before June in the Piedmont and Coastal Plains can be planted the following winter. This knowledge will help forest managers in the Southeast schedule harvesting and planting activities so as to minimize weevil damage in subsequent stands. —SE(382).

283. The introduced pine sawfly, *Diprion similis*, periodically causes defoliation and mortality of pine in Northeastern United States. The parasite, *Monodontomerus dentipes*, is very important in the control of *D. similis* populations. Information on the systematics, morphology, hosts, distribution, and life history of this parasite is reported. This information should be of great help to future workers who seek to employ this parasite against *Diprion* and *Neodiprion* sawflies. —SE(339).

284. The southern pine beetle develops poorly when symbiotic fungi are absent; yet, the nutritional role, if any, that fungi play in the beetle's development is unknown. A tenfold weight increase occurred between the beetles' egg stage and the subsequent inner bark larval stage when fungi were present. There was also a fivefold increase in the beetles' lipid content while feeding on fungus laden phloem. Recognizing that the fungus-phloem substrate apparently contributes to the lipid requirements of the beetle is an important consideration in future nutrition and rearing studies. —SO(323).

285. The nutritional requirements of the southern pine beetle and its associated fungi are unknown—a problem which exacerbates the rearing and subsequent research on this important insect. A higher percentage of short-chain fatty acids occurred in host-attacking adults than in host-emerging adults. Presumably, attacking beetles feed on the inner bark and synthesize new fatty acids while making galleries. The egg-laying stage, therefore, may also be an important nutritional stage, a requirement which will significantly aid further nutrition research on this important insect. —SO(346).

286. The mites that feed on bluestain and other fungi found in bark beetle-attacked trees are numerous and difficult to tell apart. The proper identification of these mites is essential to properly assess their role in influencing southern pine beetle populations. *Tarsonemus krantzi* was described as a new species. It had previously been confused with two other closely related species that coexist with it. This information permits continuing research on the potential use of mites as biological control agents for the southern pine beetle. —SO(379).

287. There are no known effective biological control agents for the southern pine beetle. Fifty-seven species of mites associated with the beetle in Central America and Mexico were collected and identified. Twenty-six species do not occur in Louisiana and at least nine of these are known predators of the southern pine beetle. With further study, some of these mites may be candidates for importation into this country as biological control agents of the southern pine beetle. —SO(365).

288. Toxic baits used in Latin America to control leaf-cutting ants do not give consistently good results. Generally, the attractant used in the baits, a trail-laying and trail-following chemical (pheromone), is attractive to a variety of these ants. Yet ants of at least one economically important species do not respond to the bait, presumably because they use a significantly different trail pheromone which must be identified and synthesized. Once the newly identified attractant is incorporated into the toxic bait, tropical foresters and agriculturalists will have an effective and highly selective method of minimizing defoliation by these ants. —SO(371).

289. At least two species of ants can distinguish the optical isomers of an ant alarm pheromone. One isomer is at least 100 times more potent than the other. In future pheromone research, the pheromones will have to be checked not only for chemical purity but also for optical purity if the pheromones are to work at optimum efficiency. Periodic difficulties with field tests of various attractants (pheromones) suggested the possibility that some insects can distinguish different optical configurations (isomers) of the same compound. —SO(369,370).

290. The carpenterworm causes considerable loss through defect and degrade to oaks and other hardwoods. An annotated bibliography of the carpenterworm including 206 references and covering all technical literature through 1972 was prepared. It should be useful throughout the U.S. and southern Canada to foresters, entomologists, pest control and extension personnel, students, and others who wish to refer to the literature on carpenterworm. —SO(381).

Pest control techniques

291. *Diplodia pinea* severely damages pines that are over 30 years old in plantings in the Great Plains. Effective and economical control measures for this disease have been lacking. Most of the infection of new shoots of Austrian pine occurs from the time buds open to just before needles emerge from needle sheaths. Bordeaux mixture, the fungicide, applied once during this period of development reduces infection 51 percent and two applications reduce infection 87 percent. Arborists following this spray schedule obtain good control of Diplodia blight on pine stems in eastern Nebraska. —RM(522).

292. *Lophodermium pinastri* needlecast disease has caused damage or mortality to millions of red and Scotch pines in nurseries and Christmas tree plantations in 17 States and three Canadian Provinces. Techniques for recognizing, detecting, and controlling this disease have been developed. Growers in northern and eastern Untied States and adjacent portions of Canada will be able to minimize losses by implementing the recommended procedures. —NC(521,523).

293. Scleroderris canker continues to cause serious losses in red and jack pine plantations and nurseries in the North Central and Northeastern United States. During a 3-year period, the fungicide, chlorothalonil, was more effective in controlling this disease than the previously recommended maneb and ziram, and it required fewer applications per year. Nurserymen and plantation managers now have an effective, registered fungicide for use in controlling Scleroderris in these areas. —NC(525).

294. Douglas-fir beetle is the most important pest of Douglas-fir in western Oregon and Washington, where this tree species produces one-fifth of the Nation's supply of sawtimber. A beetle-produced chemical, methylcyclohexenone (MCH), which effectively inhibits attraction of beetles to

219-692 O - 76 - 3

breeding materials, was tested in downed Douglas-fir and Sitka spruce trees in western Oregon. Two granular slow-release formulations reduced attack briefly in Douglas-fir and for 5 weeks in spruce. Practical use of this highly selective nontoxic chemical appears to be feasible for control of these destructive beetles especially if the rate of release from granular formulations can be improved. —PNW(417).

295. Information on methods for testing and evaluating microbial pesticides is very limited. A variety of techniques for evaluating *Bacillus thuringiensis* formulations and the spray equipment to be used for aerial application have been developed. This information could be applied throughout the United States wherever microbial insecticides are used to combat defoliators such as gypsy moth, Douglas-fir tussock moth, and spruce budworm. —PNW(408,410).

296. The pales weevil (*Hylobius pales*) is the most serious pest of pine reproduction in the eastern United States. The contact toxicity of 38 insecticides to adult pales weevil was determined to serve as a guide for selecting alternatives to aldrin and DDT. Several compounds were more active than either of these two materials. Recent field experiments by others using some of the more promising candidate insecticides have resulted in the registration of carbofuran and chlorpyrifos for the protection of newly-planted pine seedlings against weevil damage. —PSW(415).

297. Adoption of new techniques for sampling and controlling forest insects depends on successfully demonstrating efficacy in large-scale tests. The first successful operational use of attractants to suppress a forest pest has involved work with the western pine beetle in a ponderosa pine forest of California. With this necessary and difficult step accomplished, the use of attractants nears the fully operational stage. —PSW(398).

298. The synthetic pyrethroid, resmethrin, shows promise as a highly effective and environmentally safe insecticide, but data on environmental chemistry, which is needed for registration, is lacking for forest sites in the western United States. Residues of resmethrin were analyzed on three kinds of foliage and from water samples after aerial application of 0.05 and 0.15 lbs. per acre. After 7 days, no residue could be found on aspen and Douglas-fir; on willow, less than 0.05 ppm were detected. No residue was found in water samples. These data will be useful in evaluating the suitability of using resmethrin as an insecticide to control forest pests in the United States. —PSW(396).

299. The oak leaf roller (*Archips semiferanus*) periodically causes severe defoliation and sometimes death of oak in the Northeast. Contact toxicity tests of four insecticides (pyrethrins, bioethanomethrin, mexacarbate, and phoxim) against the larvae were conducted as a preliminary step in finding alternatives to DDT for control of this pest. All four candidate insecticides were highly toxic to the leaf roller, causing 90 percent kill with a dosage of less than 1 ug/insect. This research identifies highly promising candidates worthy of further development. —PSW(403).

300. The spring cankerworm (*Paleacrita vernata*) is a pest of shelterbelts and also defoliates forest and shade tree hardwoods throughout much of eastern North America and locally as far west as Colorado, Texas, and California. Laboratory tests of 11 insecticides were conducted to find more effective candidate insecticides. Bioethanomethrin, resmethrin, pyrethrins, phoxim, and mexacarbate were more toxic than carbaryl, the reference chemical. This research identified potential candidates with high toxicity and environmental safety, which warrant further development as chemical suppression tools for spring cankerworm. —PSW(411).

301. The cherry scallop-shell moth (*Calocalpe undulata*) defoliates wild and choke cherries over much of eastern North America, and there is presently no registered insecticide for use against this insect. The contact toxicity of 10 insecticides was evaluated as a guide for the selection of candidates for field testing. In a comparison of the insecticide response of this insect and four other forest geometrids, pyrethroids were always the most toxic and malathion the least toxic. Other researchers seeking to develop control recommendations for this insect can select from the several candidate insecticides that were identified as having sufficient potential to warrant further evaluation. —PSW(416).

302. There are presently no registered insecticides for aerial suppression of the Douglas-fir tussock moth, which periodically causes severe defoliation and killing of Douglas-fir over extensive areas of Oregon, Washington, Idaho, and other western States. Field tests were conducted with mexacarbate, trichlorfon, carbaryl, and bioethanomethrin against the tussock moth in Oregon to evaluate their efficacy in killing larvae and protecting foliage. Formulations were applied by helicopter to replicated plots up to 500 acres in size. Results were inconclusive although all four candidates showed enough potential to warrant further testing. —PSW(426).

303. There are presently no chemicals registered for use in the aerial suppression of the pine butterfly *Neophasia menapia* which periodically reaches epidemic levels in ponderosa pine stands and causes up to 90 percent mortality in the Western United States and Canada. Aerial application of 0.15 and 0.30 pounds per acre of mexacarbate in Montana reduced populations 97 percent. *Bacillus thuringiensis* provided a 73 percent reduction at 0.5 pound/acre and 92 percent, an evaluation of defoliation effects. These tests provide the data needed for planning pilot control projects to further develop these materials for control of the pine butterfly. —PSW(399).

304. Effective, environmentally-acceptable control methods are needed to protect high-value Douglas-fir forests from the Douglas-fir beetle. A repellent-type of pheromone, methylcyclohexenone (MCH), reduced beetle attacks on down logs by 96 percent in Oregon, Washington, and Idaho. These findings established MCH as potentially useful in pest management systems for the Douglas-fir bark beetle in both coastal and interior Douglas-fir forests. —INT(402).

305. Outbreaks of spruce beetle have killed several billion board feet of spruce in northern and western parts of the United States during this century. In Idaho, the natural antiaggregative compound of the Douglas-fir beetle, methylcyclohexenone (MCH), suppressed the attraction of spruce beetles to spruce logs by 99 percent. This success in modifying spruce beetle behavior justifies further work with MCH to develop control strategies for this insect. —INT(405).

306. The Douglas-fir beetle is an important killer of Douglas-fir in many areas of the West, and satisfactory techniques for controlling this insect are lacking. The "confusion strategy" which involves area-wide application of the Douglas-fir beetle attractant Douglure to confuse and disperse beetles was tested in Idaho. The method shows promise for reducing damage, but the intervals between baited trees must be reduced to disperse the beetles over more trees. This information will permit more effective additional testing of the "confusion strategy" for the Douglas-fir beetle. —INT(414).

307. A severe outbreak of mountain pine beetle is currently underway in the Front Range of the Colorado Rockies, and elsewhere in the region. The cause is probably related to the

presence of large areas of susceptible forests. What to do about it depends on land managers' objectives. Researchers and pest control specialists propose combined programs of suitable control methods. —RM(423).

308. Cacodylic acid has potential for bark beetle control, but timing of application has been a difficult problem. The results of field tests in Colorado indicate that the material can be usefully applied to ponderosa pine during a brief period following mountain pine beetle attack. Careful timing of applications will enable users to achieve optimum results with the control method. —RM(422).

309. Pinyon needle scale is a pest of pinyon in a variety of situations in the Southwest. A noninsecticidal control method using a stream of water to wash eggs off infested trees was found effective in field tests in New Mexico. The method has excellent application potential in urban areas where impact of the pest is often most severe. —RM(400).

310. The pine tip moth stunts the growth and renders unsightly several pine species in the Great Plains, but residual contact insecticides frequently have not provided adequate protection. In field tests in Nebraska, carbofuran or phorate at 10 lb./acre in the nursery or 2 oz. per inch of trunk diameter in the soil around ornamental and windbreak trees gave good protection. Carbofuran or dimethoate sprays also worked well in nurseries and plantings, but timing of dimethoate application was critical. Systemic insecticides can provide good long term control of this very damaging insect. —RM(419).

311. Freshly planted red pine seedings are vulnerable to injury by white grubs and other agents. Seedling mortality by white grubs accounted for 24 percent loss over a 5-year period when not chemically treated. Less than 4 percent of the aldrin-treated seedlings were lost to white grubs. Aldrin has no obvious effects on the nongrub mortality agents as canker diseases, root rots, and J-rooting caused as great or greater mortality in aldrin-treated plots as in the untreated plots. Although aldrin significantly reduced white grub-caused mortality, other mortality-causing agents must be minimized to successfully establish pine plantations in the Lake States. —NC(401).

312. Parasites are often used to attempt control of new gypsy moth infestations, but difficulties have arisen with obtaining sufficient numbers of healthy parasites when needed. A new radiographic procedure permits observing and quantifying the development and mortality of parasites. This technique will permit screening to assure using only viable parasites for field release. Persons responsible for controlling gypsy moth populations throughout the country will benefit from this new information. —NE(409).

313. Management of gypsy moth populations has involved using several techniques to control their numbers, among which is the application of the bacterium *Bacillus thuringiensis*. A newly developed high-potency strain of this bacterium has shown considerable promise for controlling gypsy moth. A large three-State test proved the operational feasibility of using this material and was the principal source of information for its registration for aerial use against gypsy moth. Persons with gypsy moth control responsibilities in the Northeast will benefit from availability of this technique. —NE(406,427).

314. Field testing of new toxicants against the gypsy moth is necessary to expand the chemical diversity of control programs. Helicopter applications of Gardona failed to control this insect. Treatment failed because: (1) The wettable powder formulation did not adhere to the foliage; (2) the test area experienced above average precipitation after spraying; (3) the spray deposit and residue were highly variable, and (4) the chemical lacked sufficient toxicity against the target insect under field conditions. Gardona is not considered a suitable chemical for gypsy moth spray programs. —NE(397).

315. The pales and pitch-eating weevils are the most important insects in first-year pine plantations in the eastern United States. A laboratory bioassay using wafers of elder pitch was used to evaluate 28 compounds as feeding deterrents for pales weevil. Fourteen of the compounds which significantly deterred feeding were then bioassayed by measuring the amount of feeding on pine twigs dipped in the compounds. Carbaryl, Benlate, mexacarbate, and Dexon were sufficiently promising as feeding deterrents to warrant field testing. This information will aid researchers in formulating future research to minimize more effectively losses from these damaging weevils. —SE(424).

316. Orthene is a relatively safe systemic insecticide which might be useful for the control of pine reproduction insects but data on distribution and metabolic fate within the treated plant were lacking. Chromatographic and radiochemical analyses show that Orthene was absorbed rapidly from nutrient solution and distributed through 130-day-old loblolly pine seedlings within 1 hour after treatment. Orthene was converted to its primary metabolite, Monitor, and an unknown compound which were insecticidally active against adult pales weevils. Orthene should be considered as a candidate for field tests of insecticides to control pine reproduction insects throughout the country. —SE(425).

317. To design a selectively toxic chemical insecticide one must exploit biochemical differences between insects and mammals. Work with the insecticide dimethoate has shown how modification of chemical structure can increase toxicity. An extension of this research with materials to control the southern pine beetle will, if successful, be of benefit to forest land managers in the South. —SE(404).

318. In the southern United States, pales and pitch-eating weevils can cause up to 90 percent seedling mortality in plantations established on recently harvested pine lands. These weevils can be controlled with silvicultural or chemical techniques. Information on these techniques has been made available in popularized form. This information will be very helpful to southern forest managers and private landowners who need to control weevils on their pine lands. —SE(421).

319. Forest managers have been puzzled for years by the intermittent recurrence of southern pine beetle outbreaks in certain areas of the West Gulf Region. Five years of data from 2,960 chemically treated infestations indicated a tendency for infestations to recur in high-density, pure pine sawtimber. In the last 4 years, 29 percent of the spots was associated with lightning strikes. Results will be used by researchers in the development of a stand risk/hazard rating system for the southern pine beetle. —SO(407).

320. Eighteen States have enacted legislation which regulates the activities of the structural pest control (SPC) industry whose services cost homeowners about $200 million annually, but neither these laws and regulations nor their efficacy have ever been analyzed and compared. In several States, legislation appeared to improve SPC services, but the marked lack of uniformity and reciprocity of existing legislation suggests that a model SPC law, developed by responsible interested parties, could be worthwhile. Because the content, enforcement, and uniformity of regulations determine their value, and because all States will pass legislation in response to the Federal Environmental Pesticide Control Act, this report should be of value to the SPC industry, State regulatory agencies, EPA, and indirectly to the homeowner. —SO(420).

321. Anthracnose leaf spot is the most serious disease affecting black walnut. In a test of eight fungicides applied to a young plantation in southern Illinois, Benlate 50W was most effective in reducing leaf spotting. When this chemical becomes registered, it can be used by land owners to protect walnut plantings. —NC(822).

Pest management strategies

322. There is considerable debate among foresters and pathologists as to the importance of dwarf mistletoe infections on the boles of ponderosa pine. In a study conducted in Colorado, it was found that infections on boles 5 inches in diameter or larger are generally of low vigor and, consequently, are not likely to cause infection on surrounding trees. To control the disease, the forest manager need not remove large trees with bole infections or those with bole infections plus prunable light branch infections. —RM(526).

323. Fusiform rust deforms, degrades, and kills pines throughout the South. Landowners with high incidence of rust may suffer more damage than they realize. Infected slash pine stands have been examined and management recommendations formulated for various levels of infection. Forest managers in South Carolina and Georgia can now appraise and react to their own situations more accurately. —SE(527).

Improving the Water Resource

Water quality

324. Baseline water quality data from undisturbed areas are necessary for assessing impacts of land management practices. In a relatively undisturbed area of the Wasatch Mountains of Utah, suspended sediment was found to be negligible and chemical quality excellent. However, bacterial load indicated some pollution by warm-blooded animals despite exclusion of livestock and minimal presence of man. —INT(150).

325. Nutrients and sediment are subject to removal from forest lands following timber harvesting, with possible adverse effects on forests and water. At Hubbard Brook in New Hampshire, deforestation and growth repression with herbicides for 3 years caused minor increases in particulate content (sediment) of streamflow the first 2 years and a 15-times increase the third year. Dissolved substances increased the first 2 years and returned to previous levels about 4 years after cessation of herbicide applications. Results suggest that a forest ecosystem can recover rapidly following deforestation while minimizing the effects of erosion. —NE(148).

326. Impacts of forest clearcutting on water quality are a continuing source of concern. In a West Virginia study, 78 acres of hardwoods were conventionally clearcut on an 86-acre watershed. Effects on water temperature, pH, turbidity, and dissolved solids were negligible the first 2 years. There was a temporary increase in nitrate nitrogen and phosphate, and a decrease in calcium and sulfate. Success in avoiding damage to water quality was attributed to careful road management, retention of a forest strip along the stream, and rapid, lush vegetative regrowth after clearcutting. —NE(147).

327. Because quality can rarely be determined for entire bodies of natural water, samples must be relied upon to estimate these data. This paper reviews where, when, and how to sample; frequency, size and contamination of water samples; and some of the mechanics of handling them. Sampling procedures should be considered in the planning stages of any water quality study. —NE(146).

328. Increased concern over groundwater contamination has created the need for new, improved methods of collecting data. A sampler was developed for obtaining water samples at predetermined depths. The sampler permits determination of gradients of contaminants in a groundwater system. —NC(152).

329. Finely divided logging debris may reduce the oxygen level in forest streams. Water from a typical Oregon Coast range stream was sampled and tested for biochemical oxygen demand (BOD) of the debris. The BOD of leaf material exposed to fluctuating temperature exerted a 5-day BOD 4.0, 2.4, and 4.2 times greater than the standard temperature BOD_5 for Douglas-fir needles, western hemlock needles, and red alder leaves, respectively. This study will be useful in developing a predictive model for management of forested lands for water quality. —PNW(153).

330. Finely divided logging debris may seriously reduce the oxygen level in forest streams. Management recommendations have been formulated as a result of research in the Pacific Northwest on the problem. Unless suspended above ground, logs should not be yarded across streams. Slash should be kept out of streams. Slash which enters an important fish stream should be removed quickly. These guidelines are important for maintaining high quality stream habitat for fish and aquatic organisms. 1. —PNW(154).

Water yield and timing

331. Effects of differences in water use by pine and hardwoods on streamflow have been hypothesized, but, until recently, were unmeasured. Fifteen years after two experimental watersheds in the southern Appalachians were converted from a mature deciduous hardwood cover to white pine, annual streamflow was reduced about 20 centimeters (20 percent) below that expected for the hardwood cover. Managers now have documentation that substantial changes in streamflow will occur when hardwoods are converted to pine. —SE(129).

332. Effects of land uses or treatments on water infiltration and runoff are not adequately recognized in land use planning or management. Studies reveal hydrologically better soil conditions under forest cover as compared to cultivated or grazed areas on the same soil type. Findings indicate that land managers should consider the importance of the hydrologic consequences of land use decisions. —PSW(111).

333. Current methods of forecasting streamflow from melting snowpacks are inadequate to meet needs of modern hydroelectric power plants. The profiling isotope snow gage has resulted in more accurate determination of beginning of snowmelt in the Columbia River Basin. Proposed procedures should result in more accurate forecasts of streamflow. —PSW(102).

334. A better understanding of the behavior of snowpacks is essential to effective management of water resources. Soil temperature was found to have no effect upon midwinter and spring snowmelt. Water moves through and from the packs each month of the winter. Forest management practices can influence snowmelt timing and thus the time of delivery of water to streams. —PSW(125).

335. Free water (liquid phase) content of snow varies as timber cover is changed. A measurement system is needed wherein profiles of free water content may be periodically determined under different timber cover conditions. A system is under study in which microwave and gamma sources and detectors positioned opposite one another yield profiles of den-

sity and liquid phase water content of the snowpack. With both density and free water profiles available, the condition of the snowpack can be accurately determined and, when combined with meterological information, useful predictions can be made regarding the melting and water discharge rates from snowpacks. —PSW(103).

336. Land managers need a method of predicting the amount and location of additional solar light reaching the forest floor as a result of timber harvest. The amount of sunlight and heat reaching the surface is affected by shadows cast by surrounding vegetation. A technique and a computer program and tables have been developed for calculating the extent of boundary shading for any combination of date, slope, and aspect. This information can also be used to predict changes in stream temperature and snow accumulation or ablation. —PSW(81).

337. Timber cutting to increase water yield may pose a threat to water quality. In New Hampshire, water yields during normally low summer flows were increased an average of 11 acre inches per year from a deforested watershed and about 1.5 acre inches per year from a watershed where one-third of the timber was cut in parallel strips. Nutrient release and sediment were greatest in the deforested watershed. Nutrient losses after recent commercial clearcuttings in the White Mountains were intermediate between the deforestation and strip-cut treatments. Municipal watershed managers should weigh these results when forest treatments are considered. —NE(91).

338. In order to manage forests in the northeast for increased water yield, we need more information about forest evapotranspiration and how it is altered by land management practices. In a strip-cut forest in New Hampshire, opening and closing of leaf stomata was observed as an indicator of transpiration. Results suggest that a single large clearcut will reduce evapotranspiration more and provide greater water yield increase than cutting the same forest area in a number of smaller blocks. —NE(67).

339. An inexpensive soil-water sampler that uses a miniature porous ceramic cup and a surface storage container was designed. The new sampler eliminates field transfer and permits immediate preservation of the sample. It can be enclosed to discourage vandalism. —NC(85).

340. Availability of soil water is a major factor affecting transpiration, but little is known about the effects of this factor on Northwest conifers. Under decreasing water potential, transpiration rates of ponderosa pine, lodgepole pine, Douglas-fir, grand fir, and Engelmann spruce seedlings were measured. At a potential of -10 bars, transpiration rate of the pines was only about 12 percent of their maximum rate. The transpiration rate of firs was 27-37 percent of maximum. Spruce was intermediate in response. From a watershed standpoint, pines should be more economical users of water than species less responsive to soil drying. —PNW(105).

341. A portable instrument for rapidly determining thermal conductivity of liquids and solids has been adapted to measurement of snow density. Measurements can be directly calibrated from the known relationship between snow density and thermal conductivity. Readings made in a few seconds compare favorably with the customary thermal conductivity analysis in which a time-temperature relationship developed over many minutes is normally required. —PNW(71).

342. Lodgepole pine is being harvested in small patch cuts which may have a favorable influence on water yields. Small clearings in Wyoming forests affected the pattern of snow distribution but not the total amount of snow in the area. Melt rates in the clearing were about twice those in the interior forest zones. The differences in snow accumulation and melt must be considered when evaluating the effects of timber harvests on snowpacks and water yield. —RM(78).

343. Land managers need a comprehensive report which will bring them up-to-date on the effects of pinyon-juniper control on multiple uses. A status-of-knowledge report substantiates that: (1) Mechanical methods of pinyon-juniper removal are not likely to increase water yield; (2) removal of pinyon-juniper overstory by herbicides can increase water yield; (3) there has been no statistical verification of changes in flood peaks or water quality due to treatment; (4) herbage yields increase after virtually all pinyon-juniper treatments, but potential livestock carrying capacity varies greatly due to differences in plant composition; (5) the response by deer to these treatments is, on the average, neutral; (6) the more successful conversion projects just about break even from a benefit-cost standpoint under 1972 economic conditions. —RM(55).

344. Feasibility of increasing water yield by removing deep-rooted brush and replacing it with grass depends on how much water can be produced and how conversion affects other resources. If treatment areas are kept small and interspersed with brush, water yield and forage for livestock are increased while wildlife habitat and esthetic values are preserved. Over the long run, conversion should reduce erosion by reducing or eliminating the heavy erosion cycle set off by periodic wildfires in unmanaged chaparral. —RM(90).

345. The effect of vegetation type conversion on water yield varies with density of the shrub cover and precipitation. Two small watersheds typical of sparsely covered brush fields were treated with herbicides to test the effect of conversion on water yield and erosion. Annual streamflow was increased slightly. Sediment yields were decreased due to the stabilizing influence provided by increased grass and forb cover. Data from this study suggest that changing vegetative cover from brush to grass is probably not justified because of the low return in water yield. —RM(94).

Managing, rehabilitating, and improving watersheds

346. Planting and seeding of denuded areas often fail because of inadequate or excessive rainfall. A method was developed for Utah and other Intermountain States utilizing a representative rainfall record and an analytical smoothing procedure. A reliable method of estimating the probability of consecutive rainless days will help avoid future planting failures. —INT(64).

347. Bedrock plays an important role in determination of quality and quantity of streamflow. Bedrock influences water yield through its effect on deep seepage, interbasin transfer, and storage and release of water. Chemical and physical characteristics of bedrock influence nutrient cycling and erosion rates, which in turn influence water quality of streams and lakes. —INT(110).

348. One of the major remaining problems in establishing pine on eroded areas of the southern Coastal Plain is to improve first-year survival on droughty soils. This problem was studied in northern Mississippi by testing the effect of two transpiration retardants on survival, height growth, dry matter accumulation, and water use of loblolly pine seedlings. Height growth was unaffected by the chemicals, but root and needle weights were less than those of the controls after one growing season. Seedlings treated with retardants and then subjected to drought conditions survived no better than the untreated seedlings. —SO(108).

349. Although water quality is the most pressing immediate problem in the South, quantity of water from forest land is also important in land use planning. Management of hardwoods for sustained yield can increase water supplies by 0.5 to 2 acre-inches annually. Conversely, anticipated conversions from hardwood to pine in the South could reduce available water supplies. Protection or improvement of hydrologic performance of forest soils will become an important element of forest land use planning. —SE(61).

350. Reliable estimates of discharge are needed for selecting proper culvert sizes and for designing bridges. Discharges for several intervals of flood recurrence were developed for forested drainages in western North Carolina. Tables for several types of culverts are presented for ease of selecting proper culvert size, provided discharges are known. Flow values allow greater accuracy in estimating flood discharge and more economy in design of structures to carry flood water. —SE(60).

351. The determination of surface area and biomass of trees per unit area of land is needed in order to understand the flow of energy, nutrients, and water through forest ecosystems. Measurements and procedures used to estimate surface area and biomass were compared for a 10-year-old white pine stand. Stratified two-phase sampling gave the best estimates of three methods tested. The results are being used in evaluating the influence of the forest on streamflow and the cycling of elements through the forest. —SE(130).

352. The amount of solar irradiation reaching a mountain slope is an important parameter for describing the climatology of the slope, but actual data are not easily obtained. This publication shows that, without onsite measurements being made, the intensity of solar radiation on mountain slopes can be determined. It can be estimated by using slope factors derived from tables and measurements of global solar radiation on a horizontal surface, provided the measurements are for similar cloud and atmospheric conditions. This estimation method has application for land capability mapping and for use in snowmelt, evapotranspiration, and plant growth models for mountain land. —SE(133).

353. Surface area of foliage in a hardwood stand is an important parameter in assessing transpiration and photosynthesis. An optical planimeter for measuring leaf area of broadleaf species is described. This instrument is easy to use, compact and portable, and is capable of measuring leaf areas for a variety of species. —SE(80).

354. Basic information is needed on substances causing water repellency in certain soils of the Southwest. Litter burned over a column of sand produced water repellent substances of important chemical nature. Both polar and nonpolar substances moved into the underlying sand during burning. After burning, heat moved downward, fixing the more polar hydrophobic substances. The less polar substances revolatized, broadening the water repellent layer. Temperatures over 250°C were required for fixing and revolatization. The study provides information to achieve goals directly applicable to watershed management problems. —PSW(120).

355. Almost all good reservoir sites in California have been occupied, so it is important to preserve the capacity of present reservoirs. Depositions in 48 northern California reservoirs were quantitatively related to watershed, streamflow, snow frequency, and land use variables, including 10 different classes of roads. Streamside location of roads caused the most sedimentation, twice that of other locations, with improved secondary roads near streams being the greatest contributor. Differences in sedimentation associated with roads give planners a quantitative basis for choosing among alternative locations and designs of roads in forest areas. —PSW(46).

356. Meltwater from the snowpack may be the source of important nutrients for vegetation, soils, streams, and lakes. These chemical inputs were estimated for snowpacks in the White Mountains of New Hampshire. The snowpack, just before spring melt, contained about 50 percent of the total calcium and 25 percent of the total nitrate and sulfate measured during the winter precipitation period. Potassium stored in the snowpack just before melt was nearly twice that measured in the incoming winter precipitation. Nutrients stored in the snowpack accounted for less than 10 percent of the amount lost in spring streamflow. A better understanding of the nutrient cycle will help in managing forests to sustain soil and water productivity. —NE(92,93).

357. Public resistance to certain timber harvest practices has stimulated a search for logging methods more acceptable to the public. The CHUBALL, a cable logging system, and URUS, a portable skyline system from Austria, were tested on the Fernow Experimental Forest in West Virginia. The tests were brief, but it appeared that environmental values are protected during timber harvest by these methods. Further tests, particularly economic studies, are needed before the systems will be fully accepted by commercial loggers. —NE(79,139,141).

358. European larch is a promising species for planting old fields in the unglaciated portion of the upper Mississippi Valley. Observations suggested that its thick litter mat may shed rainfall that could contribute to floods. Further study indicated that larch litter did shed some rain but not enough to be of significance. —NC(118).

359. Livestock grazing is a common practice on steep slopes of the upper Mississippi Valley's unglaciated region. Heavily grazed pastures are a major source of floods. Their contribution to floods drops sharply soon after cessation of grazing, however. Runoff from two small, open pastured watersheds was similar; but by the third year after cessation of grazing on one watershed, runoff had dropped sharply. After 3 years without grazing, a heavy mat of bluegrass blanketed the ground, and the soil was much looser. —NC(119).

360. Relating trout habitat and biological responses to sediment sources and sediment discharge is dependent on measurement of total sediment movement. A method of using sills for sampling total sediment load in streams was developed. The method permits measurements of bedload in addition to the more commonly suspended sediment component. Field data indicated that the "sill samples" probably provided better measurements of total sediment dishcarge than traditional "stream samples" do. —NC(82).

361. In managing watersheds, it sometimes becomes necessary to remove deposits of sediments in streams. Sedimentation basins are an effective way of trapping and removing bedload sediments. As a management aid, guidelines have been developed for using sedimentation basins in streams. —NC(83).

362. Large natural gas and petroleum pipelines that cross forested wetlands often block normal water flow, raising the water table on the upslope side. The high water table significantly reduces tree growth or even kills the trees. In north-central Minnesota, such damage has been prevented on the Chippewa National Forest by excavating ditches during pipeline construction to provide the necessary cross drainage. —NC(50).

363. Peat deposits in watersheds of the Lake states have been considered as natural regulators that maintain stream-

flow during summer months. Recent studies have shown that most streamflow from peatland occurs in the spring, and distribution of flow is not significantly different from mineral soil watersheds. Except for groundwater bogs, peat and bog lands release water too slowly to maintain streamflow during dry summer seasons. Peat deposits may provide temporary short-term storage to reduce storm flow runoff peaks after summer drying periods when bog water tables are low. —NC(47).

364. Information on water and its use in Alaska has been scattered and fragmentary. Consequently, a summary was made of the characteristics and distribution of surface waters in southeast Alaska. Data on the quality and quantity of the water resource are evaluated. Present utilization of the resource is described, and recommendations for its future protection are outlined. A section on further research needs is included. —PNW(121).

365. Almost no history exists of watershed research in the North American subarctic. Basic data on parameters, such as precipitation and runoff, are scarce; consequently, the framework for environmental understanding is very weak. A multi-agency, multi-disciplinary basic research program for the most significant subregions of central Alaska is being developed to rectify this situation. —PNW(124).

366. The species composition of soil microfungal populations in adjacent stands of red alder; Douglas-fir; hemlock, and Sitka spruce; and a mixed alder-conifer area were strongly correlated with the dominant vegetation type. Ninety-two microfungal species were isolated. The population in soils of mixed alder-conifer vegetation was intermediate between those of pure alder and pure conifer. There was little difference in microfungal species composition among soil horizons within a stand. —PNW(142).

367. Management of forest residues in the Pacific Northwest has potentially significant impacts on soil and water resources. Residue management influences soil and water resources in proportion to the amount it increases soil disturbance. Burning forest residues increases the quantity of chemicals that may reach streams, roughly in proportion to the quantity of fuel burned. Broadcast burning after logging of old-growth Douglas-fir increased loss of nutrient cations 1.6 to 3.0 times that from an unburned area. —PNW(116).

368. Almost every year, fires burn many acres of valuable forest land in the West; in 1970, wildfire destroyed vegetation on the Entiat Experimental Forest in north central Washington where hydrologic measurements began in 1959. During the second post-fire year, record precipitation triggered debris avalanches which destroyed two stream gaging stations. Measured runoff at the remaining station was 360 percent of the annual maximum during calibration. Effects, if any, of road building and logging on the watersheds were probably minor compared with effects of fire and subsequent record precipitation. —PNW(88).

369. The pine-forested Black Hills of South Dakota are an important water-yielding area, both for surface flow and ground-water recharge. The area is an island of forest and flowing streams in the broad expanse of the relatively dry northern High Plains. Available knowledge is synthesized in an in-depth appraisal which provides guides and criteria for what can and should be done to assure good management of the water resources in the Black Hills. —RM(112).

370. Avalanches are common in many mountainous areas and often threaten lives and damage property. With the tremendous increase in back-country use and second-home developments, it is important that people know how to recognize potentially dangerous sites. Avalanche-prone sites have been described and illustrated and a checklist given to help evaluate field evidence of avalanche activity. —RM(107).

371. It is difficult to predict failure of snow slab and the onset of avalanches. Tensile strength of snow varies with volume of the sample. An equation is presented that predicts tensile strength as a function of snow density for snow volumes of 1 to 10 cubic meters. Previous strength relations were mostly derived from much smaller sample volumes; small samples should be avoided when determining strength of snow. —RM(126).

372. The effects of increased snowfall due to cloud seeding on the major forest types in the Southwest is generally unknown. In New Mexico, the growth rate of spruce in an area of deep snow accumulation was compared to growth rates in an area receiving about 75 percent less snow cover. The comparison suggests that weather modification programs in the Southwest will have little detrimental effect on the annual or long-term radial growth of existing spruce forests. —RM(76).

373. Land managers must be aware of the multiresource options available to them as the demand increases for more and different mixes of services. Simulation models have been developed to predict changes in snowmelt and yield of water and timber resulting from timber harvest. Hydrologic changes and timber yields can be estimated for various lengths of time. Land managers can use the model to project changes in snowmelt and water yield and in timber growth and yield subsequent to timber harvest in lodgepole pine and spruce forests. —RM(100).

374. Conflicts between land use and the environment in the subalpine forest zone cannot be resolved without objective multiresource analysis, which accounts for both primary resource responses and their interactions. A simulation model has been developed to determine the longterm interaction between water and timber resources with regard to different silvicultural systems. The model can also evaluate the effect of road construction on erosion and sediment yields. The land manager can simulate the probable hydrologic changes resulting from different timber harvesting practices for both short and longterm planning intervals. —RM(101).

375. Research on controlling blowing snow in southeast Wyoming suggests that new engineering criteria for snow fences promise to improve the economy and performance of snow fence systems for other applications as well. Snow control systems can be designed that are unusually effective in preventing drifts, improving visibility, and reducing the formation of road ice. —RM(134).

376. Land managers now have a summary of what is known about the hydrology of big sagebrush lands and how this knowledge can be applied to accomplish management objectives. Climate, soils, vegetation, snow accumulation, and water yields are reviewed; how management practices alter vegetative composition and the hydrologic regime is also discussed. The practice of converting sagebrush lands to other herbaceous vegetation may result in a maximum of 15 percent increase in water yields. Potential for increasing water yields appears to lie in reducing evaporative losses of windblown snow. —RM(128).

377. Fourwing saltbush has been difficult to establish for erosion control and range rehabilitation in the Southwest. Mycorrhizal fungi may play a role in growth of these plants in New Mexico. Innoculation with a known endomycorrhizal fungus tended to stimulate growth. These findings provide additional guidelines for the establishment of fourwing saltbush by artificial means. —RM(144).

378. Pinyon and juniper trees have often been removed in an attempt to improve forage production and water yield, although little has been known about the actual effects of this practice in the southwest. Felling of a 13 percent cover of alligator juniper in north-central Arizona resulted in a 38 percent increase in total herbage production and a 45 percent increase in forage plant production. This shows that forage response is rather minimal when open alligator juniper stands are removed indicating that such continued practice merits reassessment. —RM(54).

379. Snow surveys to estimate snowpack water equivalent on large basins are currently uneconomical. A technique was developed to effectively estimate water equivalent of the snowpack from aerial photographs. On sites where forest stands and slopes are variable, only topographic features need to be measured. Attributes of the forest overstory must also be measured on more homogenous sites. This technique has been used by the University of Arizona and Salt River Project to forecast runoff from watersheds in Arizona. —RM(98).

380. Forest managers must estimate costs of thinning and piling projects to insure proper budgeting and expenditures of funds. A regression model was developed to predict thinning and piling costs as a function of the degree of timber basal area removed. Costs of thinning are related to basal area removals, including commercial logging. The model is being used in additional economic research studies and for timber management operations. —RM(137).

381. Opportunities for increasing water yields and other multiple use values on ponderosa pine lands have been the subject of much research in Arizona. A status-of-knowledge report describes multiple use productivity on watershed lands. Yields of timber, herbage, and water under past management and under new experimental land treatments are reported, along with information about effects on wildlife values; esthetics, flood and sediment hazard, and water quality. This report provides land managers with summarized, current information to evaluate proposed land management practices. —RM(51).

Forest Resources Evaluation

Resource inventories

382. The decade of the 60's saw some dramatic changes in use and management of Rocky Mountain forests. A sharp increase in demand for nontimber uses of forest land, growing public awareness of the forests' role in man's environment, and active concern for protection of that environment led to restrictions on certain uses of forest land and on the kinds of activities allowed in timber production. Timber managers' primary concern shifted from the relationship of cut and growth to the availability of forest land for timber production and the need to operate within budgetary and environmental constraints. Recent research describes the resource, the timber supply outlook, and some of the problems associated with increasing timber output from a shrinking acreage available for timber production. —INT(965).

383. Continuing periodic forest surveys of the various States are necessary to provide up-to-date information about the Nation's forest resources. Resurveys were completed in Delaware, New Jersey, Connecticut, Massachusets, Rhode Island, Vermont and New Hampshire. Reports of these resurveys summarize the present timber situation and changes that have taken place since previous surveys. They present data on timber inventory, annual net growth, and timber removals; and discuss trends in timber supply, timber availability, and projections of future timber supply in the respective States. —NE(957,958,963,964,972).

384. The third forest inventory of Missouri showed a commercial forest land area of 12.4 million acres in 1972, a 10.5 percent decrease from the area reported in 1959. The largest losses occurred in the prairie counties and the southwestern Ozarks. Growing stock volume increased by 5 percent to 76 million cords. Sawtimber volume increased at a more rapid rate—13 percent--to 15 million board feet. Individual reports include analyses of the timber situation and trends for various regions of the State, and provide a basis for assessing the States' contribution to the forest resources of the North Central Region and the nation. —NC(961,961,967,977,978,980,984).

385. Reports published for the southwest, southeast, and south delta portions of Louisiana show commercial forest land decreases since 1964 ranging from 5 percent in the southeast parishes to 6 percent in the southwestern and south delta parishes. Softwood growing-stock and sawtimber volumes have increased in all three geographic units, while hardwood volumes have remained about the same in some areas with decreases in others. A Statewide interpretive report will be issued when all parishes have been inventoried. These reports provide information on timber supply trends and progress of forest management in this important timber-producing State. —SO(968,969,970).

386. Almost 138 million acres, or over 70 percent of the commercial forest land in the South, qualify as southern pine sites, that is, forested uplands, excluding those growing cove-type hardwoods, that are supporting pine or show evidence of its former occurrence. More than half of these sites are dominated by hardwoods, and 50 percent of the hardwood inventory in the South is growing on pine sites. Ownership patterns, lack of capital, lack of interest and the problem of hardwood disposal have hindered conversion. New techniques of utilization may provide a market for a significant portion of the South's hardwood inventory and give impetus to converting low-grade hardwood stands to more valuable pine. —SO(976).

387. Analyses of past and current supplies of the important timber resources of Oregon and Washington have generally been published separately for geographic regions within each State. Reports published this year include totals for forest area, volume, growth, and removals as well as data for the individual regions within each State. Thus, users of this information can obtain a complete picture of the timber resource situation in each State from a single report. —PNW(959,960).

388. The first intensive forest inventory of that part of the Koyukuk River drainage lying north of the Arctic Circle was completed. Commercial forests occupy less than 5 percent of the 742,000-acre inventory unit, but, despite the northerly latitudes, support an average volume in excess of 1100 cubic feet per acre. Although generally restricted to narrow bands along drainages, commercial forests were found as far as 70 miles north of the Arctic Circle. Volumes reported for commercial forest land total 37.9 million cubic feet of growing stock and 87.8 million board feet of sawtimber. This report presents the first complete picture of the timber resource in this extensively forested survey unit. —PNW(971).

389. The fourth forest inventory of Georgia showed a decrease in area of commercial forest land since 1961. About 2 million acres were diverted to non-timber uses, but 1 million acres of new forest were added. With two-thirds of its land

area in commercial forest, Georgia has more timberland than any other State except Oregon. Volume of growing stock has increased and growth is equal to or greater than removals in all except a few counties south of the Altamaha River. Many new plantations in this area will have an impact on future growth. Statewide net annual growth per acre is the highest in the southeast. A reinventory of the Northern Coastal Plain of North Carolina also showed a decline in commercial forest land. Volume of softwood growing stock decreased, while volume of hardwood growing stock increased. Growing stock removals have increased by more than 50 percent, and softwood removals exceed net growth in 15 of the 23 counties. This is an up-to-date picture of the timber situation in these two very important timber-producing States. —SE(974,985).

390. Nonindustrial private forest land owners in the Southeast have 14 million acres which can be silviculturally treated beyond the rate already applied, and earn a 4-5 percent return. The predominant treatments are conversion of oak-pine and oak-hickory stands to pine. These investments would yield an annual increase in pine supplies of 1.3 billion cubic feet at a cost of 710 million dollars. —SE(975).

Utilization and production

391. Veneer log production in the Mid-South in 1972 increased to 2,287 million board feet, the North Central region produced 64 million board feet, and the Northeast region produced 125 million board feet. Softwood composed 93 percent of Mid-South production, an increase of 13 percent over the 1969 composition and continuing the trend of Southern pine plywood production which started in 1963. The Mid-South produced over 20 percent of the U.S. softwood plywood in 1972. Production and number of mills in the hardwood veneer industry in the Mid-South and North Central regions declined, following the trend of many years. Increased competition from improved panel products, competition from plastic and paper products, and decreased availability of high quality hardwood logs are all cited as reasons for the decline in the hardwood veneer industry. These statistics are essential to analysis of trends and prospective demand for timber for production of veneer and plywood in the United States. —SO(991,995,1001).

392. Oregon processed 10.4 billion board feet of timber in 1972 and California produced 5.5 billion board feet, both of which are an increase over the 1968 production levels. Sawmills process the majority of roundwood in both States, 60 percent in Oregon and 86 percent in California. Veneer and plywood production constitutes the next largest share. Most of the pulp input comes from mill residues, 98 percent in Oregon and 82 percent in California. Ninety-five percent of the wood residues in Oregon were utilized compared to 81 percent in California. —PNW(1005,1007).

393. Pulpwood production in the South (47.1 million cords), the Northeast (7.5 million cords), and the Lake States (4.5 million cords) all increased in 1973 above their 1972 levels with the Northeast showing the largest gain (29 percent). In both the South and Lake States, softwoods composed 73 percent of the production, but in the Northeast, hardwoods composed the majority with 54 percent. The majority of the production increase in all regions was hardwood, reflecting changes in pulping chemistry which permit the use of hard textured hardwoods and the relative scarcity of the softwood resource. The use of plant residues for pulpwood continues to increase in all regions, particularly in the South, where it rose 27 percent. Pulping capacity increased 5 percent in the South from 1972-1973, but only rose 1.5 percent in the Northeast. Pulp products consume about one-third of total domestic industrial roundwood. Information on pulpwood production is important to all users of industrial wood and for analyses of the overall timber supply and demand situation in the United States. —SE(989,997,998,1000).

394. The South experienced its highest pulpwood prices ever in 1973. Hardwood prices were $21 per cord in the Mid-South and $28 per cord in the Southeast where pulping capacity has increased relative to the resource supply. These prices represent the largest increases on record, 20 percent in the Southeast and 14 percent in the Mid-South. In the Mid-South, the hardwood and softwood price rises were about equal, but softwood price increases in the Southeast were twice as large as hardwood increases. Information on pulpwood prices and trends reflects the relative supplies of different species and forms of raw materials, and furnishes a clue to prospective demand for these materials. —SE(988,993).

395. Forest disturbances and changes in forest areas create problems in keeping forest inventories current. Bulk multispectral scanner imagery from the Earth Resources Technology Satellite (ERTS) revealed 79 percent of the changes in forest and nonforest land, timber harvested areas, and natural disturbances in Carroll County, Georgia. Imagery for late spring and late fall are best for detecting disturbances. With some improvement in resolution, satellite imagery could be used to locate disturbed forest inventory plots and reduce ground samples for inventory updates. —PSW(1009).

Inventory and analysis techniques

396. Research in forest inventory sampling techniques resulted in 1) 3P sampling being shown feasible for remeasurement plots in successive inventories and 2) the development of a process using Convex mathematical programming for optimum allocation of available funds for meeting specified precision requirements on several variables. These results contribute to increased efficiency and reduced costs in measurement of the nation's forest resources. —SO(1015,1016,-1022,1023).

397. Substantial acreages of California forest land are not capable of supporting the stand densities indicated by normal yield tables. Stocking capability must be determined if overestimates of production capacity are to be avoided. Equations have been developed which predict the stocking capability of five areas in California using site index, physical characteristics, and the presence of indicator plants. The equations can be used to identify areas incapable of "normal" stocking and to provide adjustments of anticipated timber yields. —PNW(1019).

398. Forest land-use planners require a broad spectrum of information upon which to base their decisions. Earth Resources Technology Satellite imagery can be helpful but is limited by spatial position errors that often exceed 500 meters and low resolution that obscures forest roads and forest damage. However, ERTS images have a potential for providing the planner a broad synoptic view of the resource base and the ability to detect and monitor small changes in the forest environment down to a 5-acre minimum. With improved resolution and improved computer classification procedures, satellite multispectral scanner data should be a valuable source of natural resource information. —PSW(1017).

Bettering Silvicultural Systems

Natural regeneration

399. Seed is essential for natural regeneration but seed crops are erratic in size and frequency. Seed production estimates for lodgepole pine in central Oregon over periods ranging from 11 to 22 years indicate enough seeds were produced for a satisfactory crop of seedlings 3 years out of 4 if conditions for germination and survival were favorable. Ponderosa pine produced only five good crops in 22 years. Consequently, chances for natural regeneration of lodgepole pine in a reasonable length of time are much better than for ponderosa pine. —PNW(751).

400. The yardstick used to evaluate adequacy of regeneration is critically important. Since the early 1930's, the stocked-quadrat method has served as the principal means of evaluating regeneration on cutover areas in the West. Suggestions are given on stocking standards, plot size, sampling intensity, and other factors which will improve use of the stocked-quadrat regeneration survey system. Regeneration can be adequately evaluated if the land manager follows established procedures and has sound objectives for guidance. —PNW(777).

401. It is difficult to obtain natural regeneration of lodgepole pine on volcanic soils. Seedling survival on 19 volcanic sites near West Yellowstone, Montana is positively correlated with the amount of silt plus clay in the soil and negatively correlated with total nitrogen and available potassium. Together, these three factors account for 93 percent of the variance in first-year seedling survival. These results provide a basis for predicting lodgepole pine regeneration success on a wide range of volcanic soils in and near the study area. —INT(756).

402. Prescribed burning has been suggested as one way to enhance advance oak regeneration on sites where succession favors less desirable species. One year after a prescribed burn in a 102-year-old red oak stand in southern Wisconsin, mortality of 1-year-old red oak seedlings averaged 58 percent. Because there were more than 7,000 seedlings per acre present before the burn, rather heavy initial mortality could be tolerated provided further mortality is low. However, the fire was ineffective in reducing competition from ferns and woody shrubs. These results emphasize that one prescribed fire is not sufficient to reduce competition, but additional research is needed before fire can be used as an effective tool to enhance growth of advance oak reproduction. —NC(753).

403. Harvesting mature lowland conifers often leads to the development of lowland brush. A summary publication recommends clearcutting, followed by broadcast burning of slash and broadcast seeding to regenerate most black spruce lowland sites. Research studies are underway to provide acceptable means of reproducing northern white cedar and tamarack which provide valuable game habitats. —NC(754).

404. Effective and efficient methods are needed to eliminate unwanted vegetation left after harvesting aspen in mixed stands, so that a fully stocked stand of aspen suckers can be established. The development of aspen suckers the first 8 years after felling all unmerchantable trees was more favorable than the development following prescribed burning in northern Minnesota. Although prescribed fire can effectively control residual hardwood overstories detrimental to aspen sucker growth and survival, the long-term effect of fire is unknown. Fire is recommended only when complete felling or other methods are unavailable or impractical. —NC(755).

405. Information is needed to determine whether crop trees released in young, even-aged stands respond and maintain their crown position in the stand. The response of 7-year-old red maple stump sprouts and northern red oak advance reproduction on a fair site in West Virginia showed that release had no effect on height growth of either species but did result in better diameter growth and retention of dominance of the red maple sprouts. These results demonstrate that hardwood species respond differently to release, which makes it difficult to prescribe a release for mixed hardwood stands. —NE(758).

406. Foresters need to be able to predict the size of cone crops well ahead of seedfall so they may intelligently plan for natural regeneration of stands and for cone collection. In Alabama, longleaf pine cone crops were closely related to average daily pollen counts during the flowering period. If this relationship holds for other species and in other areas, landowners and seed collectors will be able to estimate pine cone crops from pollen counts some 20 months ahead of seedfall. —SO(747).

407. Longleaf pine seedling stands under a shelterwood canopy can be severely damaged when the overstory is harvested. A central Alabama study showed that logging-related seedling mortality is less if the overstory is removed when seedlings are 1 or 2 years old than if they are newly established or over 2 years old. Managers should schedule final removal cuts so that areas having lightly-stocked seedling stands can be logged at the optimum time. —SO(748).

408. How prescribed fires affect established longleaf pine seedlings in stands being regenerated by the shelterwood system is not clearly understood. In an Alabama study, mortality of grass-stage longleaf pine seedlings from prescribed winter burns was much greater under an overstory than in openings, and declined as root-collar diameter of seedlings increased or brown-spot needle infection decreased. In clearcut openings burned 2 or more years after logging, seedlings 0.3 inch in root-collar diameter or larger usually survived. Using results of this study, land managers can decide if advantages or prescribed fire in grass-stage longleaf pine outweigh potential losses. —SO(749).

409. Pine seed crops cannot be estimated accurately from cone counts until the number of full seeds per cone is determined. An Alabama study showed that longleaf pine seeds develop sufficiently by August to permit seed yields to be estimated from counts of full seeds exposed by bisecting cones longitudinally. By applying these results, foresters can gain additional valuable time to plan for cone collection, seedbed preparation, and other silvicultural operations that require prior knowledge of the potential seed crop. —SO(750).

Silvicultural methods

410. Regeneration of clearcuts often is difficult in the South Umpqua Basin in Oregon. Research has provided equations which relate the success or failure of regeneration or clearcuts to soil depth, soil texture, elevation, solar radiation, moisture, and temperature of the preharvest environment. This new procedure will help South Umpqua land managers determine whether or not to clearcut given stands. —PNW(766).

411. Natural reproduction has proven satisfactory for regenerating most large-scale clearcuts in southeast Alaska, but some problem sites have been identified. Alluvial stream terraces are often taken over by alder and salmonberry while steep unstable slopes are more prone to land slides following clearcutting. Clearcutting is the best silvicultural system for southeast Alaska forests, but alternative systems should be

used on problem areas where clearcutting is incompatible with other resource values. —PNW(767).

412. Effective shelterwood regeneration requires knowledge of seedling development. Two years after shelterwood cutting of true fir-mountain hemlock type in the Oregon Cascades, mortality of grand fir was 70 percent and mountain hemlock was 90 percent. Results show that an overstory basal area of at least 80 ft^2 should be kept for satisfactory fir regeneration and probably more than 100 ft^2 should be maintained if mountain hemlock is an important component of a stand. —PNW(775).

413. Lodgepole pine literature is found in many different journals and miscellaneous publications, making it difficult to determine what information is available. A new proceedings summarizes the ecology, management, productivity, and utilization of this important western conifer. It also includes a partially annotated bibliography of over 1100 references. This compiliation of up-to-date information on lodgepole pine has contributions from 17 Forest Service authors and will greatly aid researchers and land managers in developing sound plans and future programs. —INT(762).

414. It is desirable to periodically consolidate research data which are scattered in various publications and as unpublished information, and to make this knowledge available to the land manager. Detailed status of knowledge summaries have been prepared for each of the major timber types in the central Rocky Mountains to provide information on (1) what is known about the principal tree species and (2) how this knowledge can be applied in the field. This provides the busy administrator who does not have time to read the detailed reports with a general overview and evaluation of the status of knowledge for each of the principal timber types. —RM(759).

415. Much of the existing silvicultural knowledge of subalpine forests is not being used by land managers because it is either not readily available or not in a form easily understood. The current status of knowledge on the silviculture of subalpine forests in Wyoming, Colorado, and New Mexico is described in depth for the spruce-fir and the lodgepole pine types, along with published information, unpublished research, observations, and data from practical experience. These guidelines provide the best available information on recommended timber management practices to meet a variety of uses. —RM(760).

416. Sustained yield forest management has been successfully practiced for more than a decade in the Black Hills of South Dakota but information and experience are scattered. A summary paper describes present knowledge of Black Hills ponderosa pine, including silvical characteristics, behavior, and successful silvicultural tools. This compendium will guide professional foresters and resource managers in their quest to steadily improve the yields of timber and other forest resources in this valuable resource area. —RM(763).

417. A summary publication describes the present status of knowledge on mixed conifer and aspen silviculture in the interior Southwest. Relevant literature is discussed along with observations, experience, and results of unpublished research. This status report is an excellent reference tool for prescribing silvicultural treatments and guiding management decisions in complex forest types in the Southwest. —RM(769).

418. Silvicultural practices in ponderosa pine stands of central Colorado have not always considered scenic and recreation values as major factors. Modification of conventional approaches to thinning; improvement cutting, uniform shelterwood, and group selection, plus flexible standards for growing stock levels, are now available. The practices are varied to best fit the condition of each small unit of forest and to maintain diversity without abrupt reduction of scenic values. The practices can be (and are being) applied in the Montane Zone to maintain and improve forest values, and to make the stands better able to survive the current epidemic of mountain pine beetle. —RM(771).

419. Although ponderosa pine is the most important forest tree in the southwestern United States, research results and management prescriptions have been fragmentary. A new "state-of-knowledge" publication summarizes the most significant findings, both published and unpublished, during the past 60 years. This guide will be invaluable to resource managers for prescribing silvicultural treatments and multiple-use management. —RM(774).

420. The use of the shelterwood system to reproduce northern hardwood stands has often been avoided because of the potential damage to established regeneration when the overstory is removed. Damage to reproduction by overstory removal was found to be extensive in a study in northeastern Wisconsin, but was not significant from a silvicultural standpoint. Logging destroyed about 35 percent of the advance reproduction, but more than 45,000 stems per acre remained. Potential damage to regeneration should not be considered an obstacle by resource managers who wish to use the shelterwood system in northern hardwoods. —NC(768).

421. The economic and silviculture impacts of individual tree selection cutting practices on eastern hardwood forest stands are not fully known. In one case example in West Virginia, 12 years of selection cutting resulted in a $76 to $233 per acre increase in value of residual Appalachian hardwood stands, with the greatest increases occurring on the best sites. Current trends in species composition indicate that selective cutting practices will also change the species composition toward a climax stand favoring shade-tolerant, slower-growing, lower-valued tree species. These results will aid land managers involved in deciding on investments in growing timber in the Appalachian region. —NE(770).

422. There is a general misconception that sustained yield is automatic under any form of partial cutting in which trees are individually marked. A recent Pennsylvania review of what is required to make selection cutting work shows that application of various misnamed types of "selection" cutting may result in wide fluctuations in timber yield. Guidelines are presented in this review which should assist land managers in achieving a higher level of professional application of selection cutting. —NE(773).

423. Forest managers need an efficient analytical method for estimating the long-term effects of intermediate cuttings on total stand yield. A computer programming system has been developed for even-aged northern hardwoods in New England that simulates stand treatment and development, and provides thinning yields and final harvest data by species and quality classes. The simulator provides timberland owners with a much-needed management tool for quantifying the effects of alternative treatment strategies. —NE(776).

424. Improved uneven-aged management guidelines are needed to selectively manage Appalachian hardwoods. A marking procedure was recently developed that incorporates silvicultural and economic guidelines for selecting trees to cut. In practice, this procedure is applied as a flexible diameter limit using low, medium, and high rates of return on fair, good, and excellent sites. Where applicable, this silvicultural-economic marking technique is believed to be an improvement over available uneven-aged management techniques. —NE(778).

425. Although multiple-use is a valuable approach to forest management, coordinating these uses involves a number of trade-offs to reach desired goals. Theoretical multiple-use options have been developed for managing forest land in central Appalachian hardwoods, with priorities being assigned among four resources— timber, water, visual appeal, and wildlife. These options can serve as guidelines for several multiple-use decisions in conjunction with landowner objectives. —NE(779).

426. Many areas in steep mountainous terrain of West Virginia cannot be easily harvested with conventional logging equipment. A 2-month-old test of a mobile skyline yarding on the Fernow Experimental Forest using clearcutting and selection practices demonstrated that timber on steep slopes can be satisfactorily logged with favorable production and environmental results. The system is especially adapted to logging of hardwoods on previously inaccessible sites with a minimum of environmental disturbance, and has high potential for reducing the environmental impact of timber harvesting in the Appalachians. —NE(780).

427. To meet increasing demand for lumber and veneer logs, southern forest managers are being asked to produce short-rotation sawlogs. Loblolly pine sawtimber 15 inches d.b.h. was produced in 27 years on good sites in southeastern Arkansas through heavy thinning, understory control, and green pruning. At age 27, standing volume was 11.9Mb.f. per acre in intensive treatments compared to 5.3 Mb.f. in controls. But control stands had produced substantially higher merchantable cubic volume and more frequent intermediate harvests than intensively managed stands. Specific gravity was unaffected by treatment. These results illustrate the trade-off landowners must make if they wish to deliberately tailor stands for an early harvest of sawlogs. —SO(764,765).

Ecological relationships

428. Mountain whitethorn is one of the more abundant and troublesome shrubs on commercial forest land in California and southwestern Oregon. Origin of many mountain whitethorn brushfields evidently can be attributed to fire-induced germination of dormant seeds in the soil. Experiments show that heating soil can stimulate germination of buried seeds if followed by a cold, wet period suitable for after-ripening to overcome embryo dormancy. This information suggests that mountain whitethorn will not be a problem on new harvest cuttings if logging slash is not burned. —PNW(635).

429. New "state of knowledge" reports summarize the history, geography, geology, soils, as well as the forest resources and timber industry in southeast Alaska. Forest conditions and silvicultural practices in the western hemlock-Sitka spruce type and problems and opportunities for better timber management are discussed in detail. Addition of rather complete bibliographies make these reports valuable field and shelf reference sources for forest managers and land use planners in southeast Alaska. —PNW(636).

430. The most critical period in the life of a forest tree is during the first growing season. A controlled environment study on a central Oregon tree species showed that temperature lower than -5°C can result in considerable mortality of newly germinated grand-fir seedlings, if they are exposed longer than 10 minutes. By contrast, 6-month-old seedlings can withstand extended periods of temperatures as low as -18°C. Because much early mortality of grand fir may be due to early spring frosts, spring direct seeding should be accomplished after danger of freezing is past. —PNW(653).

431. Animal mortality in live traps has been a major problem for researchers studying small mammal populations during winter in northern regions. A new live trap was developed in Wisconsin which provides trapped animals with proper food and water and minimizes body heat loss. Using the new trapping technique, less than 1 percent "trap mortality" was experienced in an area where continuous snow cover is present during the winter and where ambient air temperatures in the vicinity of the trap were as low as -18°C. The trap and techniques developed should materially aid and encourage small mammal research during the winter. —NC(632).

432. The Enterprise Radiation Forest was established in northern Wisconsin in 1968 to investigate the effect of massive doses of gamma radiation in natural northern forest communities. A summary publication on this unique experimental area describes the history as well as the physical and biological environment of the various communities within the forest. The 13 chapter compendium will serve as a common base for future ecological and radiological research in the northern hardwood forest type. —NC(652).

433. Past research dealing with the horizontal or elevational movement of forest tree and shrub species has been based on subjective or theoretical techniques or, occasionally, long-term remeasurement of plots. A new geometric method based on trends in tree age is now available for assessing the rate and direction of species movement. This procedure showed that yellow birch on Mt. Washington, New Hampshire, advanced in elevation annually at the rate of 1 meter, whereas black spruce retreated 1 meter. Application of the geometrical method replaces guesswork in studying elevational movements of tree-line and commercial types, and the recolonization rates of denuded areas. —NE(642).

434. Frequency and intensity of pre- and post-settlement fires have affected the composition of northeastern forests. A review summarizes what is known about effects of fire on composition of spruce-fir, northern hardwood, eastern white pine, oak, yellow-poplar, sweetgum, pitch pine, Atlantic-white-cedar, Virginia pine, and loblolly and pond pine types. This concise synthesis will significantly aid scientists and land managers in understanding consequences of wildfire and fire control programs. —NE(647).

435. Wild grapevines can be extremely damaging to central Appalachian hardwood trees in certain situations. Studies on the Fernow Experimental Forest in West Virginia indicate that grapevine sprouts cause more damage than grapevine seedlings because the sprouts grow much faster. Grapevines were found to be shade intolerant and developed more prolifically after clearcutting than after selection cutting, especially on the better hardwood sites. Nevertheless, grapevines also have considerable value in game management, so the results of the study are important in better understanding how to regulate the role of this plant species in multiple-use forestry. —NE(654).

436. Reliable methods are needed to estimate leaf biomass in forest stands to interpret the effects of silvicultural treatments. A new sampling technique which employed 15 or 30 randomly placed circular leaf traps per 0.1 hectare plot provided precise estimates of total leaf production; the results appeared to be repeatable for more than 1 year. The method was not reliable for estimating leaf production of individual species in mixed stands; however, this nondestructive sampling technique should prove useful to other scientists engaged in similar lines of research. —SE(648).

437. A major flood on the Mississippi River during spring and early summer 1973 provided valuable information on tolerance of hardwoods to flooding. Most bottomland hardwood plantations and natural stands that were 1 year old or

older were not extensively damaged by continuous flooding during the first 2 months of the growing season, but yellow-poplar plantations up to 15 years of age were completely killed. New plantings of cottonwood cuttings were virtually destroyed by 2 months of flooding, whereas only about half of newly planted seedlings that were under water about 2 weeks longer died. Flooding for 3 months killed 1-year-old planted sweetgum. This information will help landowners decide which hardwood species to plant on specific sites. —SO(638).

Economics of Forest Management

Methods of financial evaluation and planning

438. Combining monetary and nonmonetary values in land use planning analyses is at an early stage of development. Integrated political and economic analyses can help define goals, make clear a variety of tradeoffs, and channel planner's efforts to resolve the most critical problems. —INT(1025).

439. A computer program, MULTIPLOY, has been developed to describe the effects of forest management decisions in monetary terms. MULTIPLOY provides managers with economic analyses on losses to fire, insects, storms, or diseases; gains from genetic improvement and a number of non-timber yields. Managers are provided with a compact package for evaluating a large number of alternatives in terms of present net worth, annual equivalent income, benefit-cost ratio, and internal rate of return. This method of financial evaluation will be especially useful to forest managers making investment decisions. —SO(1026).

440. A procedure for apportioning Federal cost-share funds under the 1974 Forestry Incentives Program for silvicultural practices was developed using data on the distribution of forest area, financial returns on investments, and suitability of the respective components of the forest area to yield financial returns. Using this procedure, the South received 68 percent of the 1974 funds, the North received 31 percent, and the West 1 percent. An analysis of the sensitivity of apportionment results to data errors indicated that the overall framework of the procedure and the distribution of forest area influenced the outcome much more than reasonable fluctuations of financial returns. Though some problems remain, the apportionment system developed meets the statutory requirements with a simple procedure. The procedure and apportionment will be refined and updated as new data become available. —WO(1024,1028).

Timber growing economics

441. In evaluating timber management alternatives, analysts must often make assumptions as to relationship of stumpage price to average tree diameter. This analysis of thinning in Douglas-fir shows that not only can alternative assumptions about price-diameter relationshps produce differences in present net worth for given stands, but these differences persist over a wide range of interest rates. Choice of assumptions about price-diameter relationships should not be taken lightly. —PNW(1038).

442. Basic to analysis of any investment alternative is the ability to estimate its benefits. A series of sensitivity analyses of allowable cuts showed that, under an even-flow constraint, allowable cuts are influenced by 1) long-term growth, 2) the period that growth increases must be cumulated before they can be harvested, and 3) the amount and class distribution of the initial inventory. Analysis of the relative importance of these factors under different conditions provides useful understanding of the effect of various alternatives on allowable cut. —PNW(1034).

443. A basic determinant of the level of production of wood products is the acreage devoted to producing stumpage. The trend of a shrinking land base for timber production will probably continue. Ways to maintain or increase outputs from the remaining acres through intensive management and the potential impact of limiting timber production are discussed. —INT(1039).

444. Better guidelines for managing hardwood stands by selection cutting are needed. This method incorporates silvicultural considerations with rate of return guidelines. Rates of return were developed from growth and quality data for nine hardwood species. Trees are sorted out by species, size, vigor, and quality. Those that don't make a prescribed rate of return are marked for cutting. A valuable tool for economic management of private hardwood timber tracts is thus provided. —NE(1043).

445. Hardwoods removed from pine sites could be profitably utilized in products where quality of raw material does not affect product value or yield. Sale of these hardwoods could offset conversion costs but would also narrow the difference between future values of the pine and hardwood crops. Opportunities for conversion cover millions of acres and offer the greatest potential for boosting timber supply in the South. —SO(1030).

446. As concern for conservation of our natural resources increases, the role of forest practice legislation becomes more important. Recent laws in California, New York, Oregon, and Washington have established standards to be followed when harvesting timber or undertaking other forestry operations. Foresters can contribute their professional knowledge in the public discussion of proposed forestry legislation. —SO(1042,1052,1054).

447. Millions of acres in pine plantations require mechanized harvesting. Productivity of harvesters in shortwood, long-log, and whole-tree thinning systems was estimated from machine times and true measurements on row-thinning operations in slash pine plantations. Managers contemplating use of particular machines can benefit from study procedures for data collection, analysis, and application of results. —SO(1031).

Multiple-use economics

448. To increase forage production in ponderosa pine stands, forest managers must understand the range implication of timber management plans. This study evaluates the feasibility of seeding forage in thinned ponderosa pine. Results show that important forage-seeding opportunities are associated with new ponderosa pine stocking guides. Informing land managers of these opportunities is an important first step toward fuller utilization of transitory range. —PNW(1050).

449. Decisionmakers often face conflicting arguments and data which are difficult to evaluate. Theoretical analysis of the incidence of costs and benefits of public policies shows that, where costs are not associated with receipt of benefits, there is a tendency for beneficiaries to lobby for alternatives that are not in the public interest. Decisonmakers can use the framework presented to evaluate the alternatives involved in the management of our forest resources. —PNW(1045).

450. One-fourth of Montana is forested. Forest resources are important to the economy and environmental quality of the State. This study describes the current status of Montana's forest resources in terms of forest zones, the structure of the forest land base, and the utilization of these resources

through recreation, grazing, mining, and harvesting. An understanding of the resources available and the alternative ways to manage them will be necessary to meet future demands on forest resources. —INT(1051).

451. To effectively manage timber and wildlife habitat, inventories should match the land capabilities with the objectives of the owners. Such inventories should also provide background for selecting and evaluating management alternatives. This suggests a two-stage inventory: 1) A moderately technical reconnaissance and 2) a more specialized diagnostic phase to chart paths for management alternatives. The first phase screens out irrelevant issues and saves time during the more expensive second phase by eliminating unnecessary measurements. This system enhances the consultant's efforts to meet landowner's objectives. —NE(1047).

452. Much information is available for planning multiple-use management of forest lands, but it needs to be integrated and expressed in terms usable by land managers. A planning framework and an allocation model which satisfies the stated objectives of multiple-use planning have been developed. Physical productivity and the interrelationships between products in the long term are primary considerations in selecting alternative management practices and the extent to which they are applied to maximize net public worth within the confines of sustained yield objectives. —RM(1053).

453. Benefit-cost analysis indicates chaparral-to-grass conversion is economically feasible on 146,200 of the 850,000 acres of chaparral in Arizona's Salt-Verde Basin. Extensive conversion could increase water runoff, increase animal carrying capacity, and reduce firefighting costs in the Basin. Though economic feasibility is not the sole determinant in land management decisions, this study helps put the potential for future chaparral conversion in perspective for land managers and others. —RM(1032,1044).

Impacts on forest industry and regional economics

454. Economic planners must choose planning strategies appropriate to various anticipated circumstances. This study provides the means to estimate the impact on the Douglas County, Oregon economy of changes in timber harvest, changes in appropriated funds to Forest Service and Bureau of Land Management, and changes in demand for wood products. It also provides a model for analysts to use in looking at economic impacts where raw material supply limits production. This will help planners evaluate future conditions and estimate the impact of alternative planning strategies. —PNW(1056).

455. More than 800 million slash and loblolly pines in South Carolina, Georgia, and Florida have fusiform rust stem infections. These incidence figures, applied to the entire South, indicate a stumpage loss to fusiform rust of $28 million in 1972. This loss estimate suggests the effort that can be supported to diminish future losses. —SO(1058).

456. Structural econometric models of softwood lumber markets have derived lumber supply price elasticities of roughly 1.5. Lumber demand, on the other hand, is very inelastic in the one-year-run, less than 0.5 and maybe as low as 0.2 - 0.1. The supply price elasticity of Douglas-fir stumpage was estimated to be 0.11. A lumber demand surge is translated down to the stumpage market as a stumpage price increase which in turn shifts the lumber supply function to the left. Therefore, in an intermediate length-of-run, lumber supply may be price inelastic. While demand is the originating force behind a price surge, anything which increases the price elasticity of lumber supply, and especially of stumpage supply, will decrease the severity of a price rise precipitated by a construction boom. —WO(1083,1106).

Weather Modification and Weather Effects

457. Sea breeze fronts are a fire problem in coastal forests of the eastern United States. Frontal wind shifts along with increased speed can produce severe fire behavior and jeopardize fire control activities. Procedures for predicting the sea breeze fronts using an estimate of mid-morning winds, the forecasted maximum temperature, and a set of prepared tables have been developed. More effective fire control efforts through improved weather forecasting is the net result. —SE(631).

458. When weather fronts pass through an area, there is a change in forest fire danger. Results from a study evaluating frontal passages at Brunswick, Ga. indicate the 1-hour and 10-hour fuel moisture and the burning index have a definite response. This information provides needed input for safer and more efficient fire control operations. —SE(626).

459. Prediction of fog is important to many management activities. Fog is a transfer vector of disease and other airborne activities within forests and forest-related environments. Studies in Georgia have related synoptic features such as relative humidity, windspeed, and wind direction to fog development. Additional studies concluded that accuracy of atmospheric sampling is a major factor in fog prediction. Sophisticated statistical procedures have also been developed to better evaluate research efforts. Results of these studies will enhance our ability to predict fog. —SE(621,624,626,629).

460. In order to more fully develop, model, and apply information on fire behavior, smoke dispersal, pollen dispersal, and other wind-related forest phenomena, it is necessary to determine the distribution of velocity through the forest canopy and its resultant effects. Research results indicate wind distribution in the canopy can be modeled. There is an apparent independence of wind and temperature which tends to support use of stand averages in energy balance work. A computer diagnostic model has also been developed to evaluate smoke plume configurations. The wind modeling research will materially assist our commitment to manage forest lands with minimum negative impact on air quality. —RM(617,618,623).

461. Scaling parameters are needed components for the development of bioclimatic models. Vertical air temperature profiles measured in a Wyoming pine stand indicate that maximum temperatures of composite profiles are found at the level of maximum foliage concentration and at the floor of the stand. In support of this modeling work, procedures have been developed to analyze the sensitivity of model parameters. The sensitivity analysis is important in the model verification, interpretation, and analysis. Modeling work is an integral part of our efforts to continually improve and sustain quality forest management nationwide. —RM(619,622).

462. Diagnosis and prediction of winds in mountainous areas are needed for determination of such data as fire spread rates and potential of advection and movement of air pollution in forested areas. A new model predicts surface windspeeds and directions at remote locations on a square grid with grid points approximately 208 feet apart. Wind prediction at these grid points can be made for up to 24 hours at remote locations where few or no observations are available. The model furnishes winds and wind fields to predict spread rates of wildfire, penetration of air pollution into forested areas, or smoke trajectory from prescribed burns. —PSW(628).

463. The Forest Service will have increasing need for meteorological information in the form of observational data

and diagnostic and prognostic numerical simulations to apply to a wide range of forestry problems including fire, environmental planning, hydrology, disease and insect studies, and forest management. Results of the study show that the Forest Service, as well as other agencies, must rely on the National Weather Service for synoptic scale information, join with other regional agencies to combine mesoscale information generation, and should expect to fill its own needs for toposcale information and specialized user requirements. Numerical modeling based on scale stratification is shown to be a reasonable approach toward satisfying Forest Service meteorological needs on a limited budget. —PSW(630).

464. Managers engaged in fire danger rating and fire protection planning have a method of obtaining reasonably complete weather observations from remote areas in their districts or rating zones without having to send someone to get the data or station someone there to make the measurements. Automation of the weather observations is the answer. One effort involves the development of an inexpensive, reliable, and semi-automatic fire weather station. A second effort involves a contract with Honeywell to modify the U.S. Air Force droppable weather station to fire weather needs. The third effort is a sophisticated automatic meteorological research telemetry network. The inexpensive weather stations being developed in California are prototypes for a nationwide network of fire weather stations and the Honeywell stations are prototypes for weather stations that can be deployed around ongoing forest fires. —PSW(625).

465. Research meteorologists need a statistical procedure to analyze periodicity of temperature and wind functions over southern California. A harmonic analysis algorithm is programmed for use on the Hewlett Packard 9820-A programmable calculator. The program is versatile in its acceptance of various meteorological variables. Values are statistically tested for their relationship to original data. The harmonic analysis program provides researchers and others a quick and easy method to analyze, describe, and model periodic phenomena such as hourly values of temperature, relative humidity, and fuel moisture throughout the day. —PSW(620).

466. Lightning modification is considered to be a viable means of reducing the severity of the lightning fire load. Results show silver-iodide and metallic chaff seeding of thunderstorms are two promising means of producing lightning modification. Research is still needed to clearly identify the full potential of this new technology. —INT(606).

467. USDA Forest Service interest in modifying storms stems from the continuous destruction of forest resources by wildfires ignited by lightning. Two lightning modification experiments were conducted in Western Montana in the 1960's. A summary of this work as well as results of weather modification research undertaken at the Northern Forest Fire Laboratory are presented to aid in future research. —INT(601).

468. Irrigation in central Washington State from 1950 to 1971 produced little climatic change either inside or outside the irrigated area. Trends in summer air temperature and rainfall during July and August and open pan evaporation were examined at stations inside and outside the Columbia Basin Project. Pan evaporation gave the most sensitive measurement of the small integrated effect of irrigation on the environment of the area. The study suggests no secondary precipitation benefits accrue to areas receiving irrigation treatments under conditions like those prevailing in central Washington State. —PNW(73).

469. Residues resulting from forest harvest or natural events influence regenerating plants by altering the microclimate. Basic physical processes underlie the development of local microclimates. Opportunities to affect these processes by residue generation and treatment were examined with respect to a simplified energy balance model and by demonstrating effects of residue types on surface heating and cooling. Change in exposure and surface physical properties due to residue treatment produces important modifications of the energy balance. —PNW(70).

Reclamation of Mined Lands

470. Little quantitative information is available concerning revegetation of mine spoils in Western United States. First-year results of revegetation research at the Decker coal mine in Montana indicated that several combinations of grass seed mixtures, fertilizers, mulch, irrigation, and top-dressing produced acceptable grass stands. Top-dressing of mine overburden appears to be a desirable practice. This research project will be useful to those planning reclamation of mined land. —INT(30).

471. Guidelines have been developed for predicting the rehabilitation potential of surface-mined lands in the Northern Great Plains. The guidelines are based on: (1)Amount and distribution of precipitation, (2) suitability and availability of plant materials, and (3) soil productivity and stability. The potential for rehabilitation is greatest in such areas as west-central North Dakota, and lowest in southeastern Montana and western North Dakota. This information will provide guidance in decisions on how to conduct surface mining operations, along with a better understanding of the expected effectiveness and cost of rehabilitation. —INT(33).

472. Massive structural failure and surface erosion can take place in improperly designed mine spoil dumps and associated road fills. Spoil dumps placed on slopes of 3 to 1 or less should not be subject to failure even under saturated conditions. Streams approaching 0.8 cfs in mine dump soils will cause significant erosion. These results will be useful in planning mining and reclamation operations so as to minimize sedimentation of streams and other environmental damage. —INT(31).

473. Direct seeding of pine is an appealing method of reforesting spoil banks, but results of most field trials have not been encouraging. To pinpoint the trouble, greenhouse studies were recently made of seven pine species sown on 12 Kentucky spoils. It was concluded that the best opportunities for success are with longleaf and loblolly pine sown on sites with coarse-textured spoil with pH between 4.1 and 5.0. These preliminary results will assist in development of reliable procedures for direct seeding of plants on surface-mined lands. —NE(34).

474. Competition by herbaceous plants has often been a problem in tree establishment. In a study of plant competition on coal mine spoils in eastern Kentucky, herbaceous vegetation did not significantly affect tree survival, but tree growth was suppressed by grass cover. On the other hand, tree growth was enhanced in cover dominated by legumes. Chances for establishing trees on mine spoils seeded with herbaceous species can be increased by encouraging rapid establishment of legumes and avoiding strongly competitive grasses. —NE(41).

475. Reclamation of refuse from underground bituminous mines is a major problem in Pennsylvania. Chemical characteristics of the spoil refuse appear to be responsible for limiting plant growth. On most areas, lime, fertilizer, and mulch

were essential to the establishment of weeping lovegrass, K-13 tall fescue, Korean lespedeza, and red pine. A vegetative cover on these spoils enhances their esthetic qualities and reduces dust, erosion, and water pollution. —NE(28).

476. Herbaceous vegetation is usually planted on mine spoils only in the spring. However, this has not always provided cover in time to prevent erosion. On mine spoils in eastern Kentucky, procedures have been developed that will provide vegetative cover within 45 to 60 days after seeding from March 1 to October 15. For summer seedings, warm season, annual species were especially useful for providing quick cover. Seedbed preparation was found to be essential for successful seedling establishment. —NE(42).

477. Use of fly ash from power plants for reclamation of surface mining offers an attractive outlet for large tonnages of this waste material. A study describes changes that occurred in spoil in West Virginia following the application of 150 tons of fly ash per acre. The treatment neutralized acidity, added plant-available phosphorus, lowered spoil density, and increased subsurface moisture. The results may encourage greater use of this waste material for the reclamation of drastically disturbed areas. —NE(38).

478. Planting success with containerized tree seedlings has encouraged use of this system on coal mine spoils in Pennsylvania. Plastic tubelings were found to be subject to serious frost-heaving, however. Of the containers tested, peat pots and Jiffy-7's were most resistant to frost-heaving. Compared with bare-root seedlings, seeded red pines in peat pots and Jiffy-7 containers performed well. —NE(29).

479. There is much variation in growth rate of Virginia pine on mine spoils due to site characteristics and genetic factors. The importance of these factors was studied on acid mine spoils in southeastern Kentucky, using seed from Kentucky and Tennessee. Seed from eastern Tennessee produced slightly taller trees. A genetic gain is possible using a process of selection, and this may be increased on sites where careful mining techniques and cultural practices have resulted in relatively uniform spoil conditions. —NE(39).

480. This field manual provides information and guidelines for revegetating surface mined lands in the eastern Kentucky coal fields. Items specifically discussed include: predicting problem spoils, problem coal seams, physical and chemical properties of spoil that affect vegetation, spoil sampling and testing, vegetation selection and establishment, site preparation and seeding methods, fertilizer selection and application, mulch selection and application, and treating acid spoils. This manual will assist those responsible for proper revegetation of mine spoils, such as mine operators and state reclamation inspectors, to do the revegetation job more easily and successfully. —NE(40).

481. Control of stream sedimentation is an important goal of surface mine reclamation. Effectiveness of mining practices and control structures in reducing sediment was studied in West Virginia. Impoundment structures removed 60 percent of the suspended sediment resulting from low to moderate intensity storms but were not always effective during severe storms. Improvements in structure design and other reclamation techniques should further reduce sediment in streams and rivers. —NE(43).

482. Little quantitative information has been available about the effects of various mining practices on erosion and sedimentation. Recent measurements of sediment accumulation in debris basins below surface-mined lands in eastern Kentucky show highest sediment yield during the first 6 months after mining. Erosion and subsequent sediment yield appears to have a half-life of 6 months. Results of this study suggest that if the amount of sediment produced during the first 6 months is known, it may be possible to predict the yield for any 6 month period or the total yield. —NE(27).

483. Successful stabilization of surface-mine spoils and other drastically disturbed areas depends on the establishment of a grass and legume cover. Mulches and soil stabilizers may be used on problem sites to help establish vegetation and reduce erosion. Two cooperative demonstrations in West Virginia compared vegetation establishment and erosion loss following 30 treatments with 6 mulches and 12 soil stabilizers. There is no evidence that these materials are necessary for vegetation establishment; they are used primarily to control erosion. —NE(37).

484. Over the years, spoil slides have disturbed thousands of acres in Appalachia. These slides result in an unnecessary loss of natural resources, and their raw surfaces intensify the quantity and persistence of sediment and chemical pollution of streams that drain mined watersheds. An investigation of the causes of slides in contour strip coal-mines in eastern Kentucky revealed that the incidence of slides is not related to steepness of terrain. Storage of spoil on excavated benches reduced the area disturbed by slides 42 percent. Instability of spoil dump outslopes is still excessive, but can be reduced as knowledge of physical and mechanical properties of spoils is developed and applied. —NE(44).

IMPROVING UTILIZATION AND EXTENDING WOOD SUPPLIES

Intensive Culture Methods

Site evaluation and soil improvement

485. It is difficult to obtain accurate estimates of cubic foot volumes in scaled logs. A review of current scaling practices in the Pacific Northwest shows dropping fractional diameter measurements results in lower recorded diameters than those obtained by measuring to the nearest one-tenth inch. This biases cubic volume estimates by 10 percent or more in small diameter logs. Fractions should be retained or recorded diameters should be fully adjusted to get accurate cubic measurements using sawlog scaling procedures. —PNW(867).

486. What cultural measures should managers use in coastal Douglas-fir stands? A review indicates a 30 percent gain in yield can be obtained from a combination of precommercial and commercial thinnings. Further substantial gains can be expected from fertilization and genetic improvement. Recent information brings these and other considerations into proper perspective in evaluating opportunity and expected benefits from intensive management of Douglas-fir stands. —PNW(663).

487. Even though there are extensive commercial forests in southwest Oregon, little information on how to increase tree growth is available. In a 30-year-old, Site IV stand of Douglas-fir, fertilization increased average 4-year basal area growth of dominant trees by 57 percent over control growth on a clay loam soil. Thinning increased growth by 53 percent. When combined with thinning, fertilizing increased growth by 94 percent on the clay loam soil and 132 percent on a nearby sandy loam soil. Both fertilization and thinning can be used to increase tree growth on dry Douglas-fir sites. —PNW(675).

488. Prescriptions must be improved if fertilizer is to become a practical silvicultural tool. Nitrogen fertilizers increased basal area growth of 75-year-old, codominant Douglas-fir trees on a highly productive soil in western Washington. Although the six treatments tested increased average 5-year basal area growth by 17 to 53 percent over control growth, only ammonium nitrate at 300 pounds of N per acre increased growth significantly over no treatment. Increased growth from fertilized mature stands provides high value wood which can be quickly harvested. —PNW(674).

489. Lodgepole pine often occupies frost pocket areas in central Oregon to the exclusion of ponderosa pine. Previously, it has been shown that lodgepole pine is more tolerant to low temperatures during the seedling emergence period than is ponderosa pine. In this more recent investigation, lodgepole pine floral structures also were found to be more frost resistant than ponderosa pine. A temperature of -2.2°C killed 88 percent of ponderosa pine flowers but only 2.6 percent of lodgepole pine flowers. This information helps explain why lodgepole pine occupies flat depressions as pure stands. —PNW(681).

490. Sound guidelines are needed to develop operational fertilization programs for intensive timber culture. A recent evaluation of the important methods of diagnosing forest need for—and response to--nutrient change proposes a six-stage program for operational fertilization. The program provides an efficient and effective guide for assessing the fertility status of forest sites, the nutrient deficiencies that exist, and the quantities of nutrients needed for optimal growth. The program provides forest land managers with a guideline for fertilization decisions. —PSW(676).

491. Red pine productivity cannot be adequately estimated from soil properties, and growth response to nutrient levels is unknown. A study of 50 red pine stands in north-central Minnesota provided an estimate of site index for two distinct groups of soils: those with a well-developed B horizon or textural banding below the solum (Group I), and those without textural differentiation (Group II). Site index estimates are based on nutrients and cation exchange capacity in the surface 25 cm of the mineral soil. Nitrogen or phosphorus may be limiting tree growth in 1/3 of the stands. The most likely fertilizer responses should come from phosphorus in Group I soils and nitrogen in Group II soils. Improved estimates of productivity for red pine forests can now be made from soils information before planting. —NC(655).

492. Variations in forest soils cause difficulty in adequately and efficiently sampling soil chemical and physical properties for use in red pine and aspen management. In Minnesota, red pine or aspen stands require only two samples to estimate pH, bulk density, or sand to ± 10 percent with 95 percent confidence. Estimates of nutrients, available water, or silt plus clay, on the other hand, require 25 to 60 samples. Most properties of the forest floor require 30 to 50 samples in red pine stands, but only about half as many in aspen stands. These results provide managers with efficient means of sampling soils for specific physical or chemical soil properties. —NC(657).

493. Large scale commercial planting of Caribbean pine is now underway in Peninsular Malaysia, but is hampered by the lack of specific information on growth and yield of this species on the large variety of soils found in Malaysia. A recent cooperative research venture showed that Caribbean pine makes very rapid height growth on soils developed from granite—10-year-old trees averaged about 65 feet tall. Poorer height growth occurred on soils developed from shale and sandstone, but growth was often improved by phosphorus fertilizer. Growth of Caribbean pine in Malaysia is equal to or better than in most other tropical countries. These results will be useful to forest land managers in Malaysia in identifying the most productive sites for Caribbean pine plantations. —NC(661).

494. Site index curves constructed from regional data are not suitable for determining site index from height-age data in Missouri, particularly at ages less than 50. New site index tables, factors for converting site index of one oak species to that of another oak species, and confidence intervals based on number trees measured for Missouri conditions are now available. This information will be especially useful to land managers in accurately determining site index for oaks in one major section of the central hardwood region. —NC(672).

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495. Nutrient concentrations in forest tree leaves are used to evaluate possible response to fertilization, but little is known about the sensitivity of leaf parts to changes in external nutrient supply. A study in West Virginia showed that yellow-poplar leaf blades are more responsive to changes in external nutrient supply than petioles or whole leaves. Blades provided a more sensitive and accurate measure of nutrient concentration than petioles or whole leaves. These results clearly show that for comparable and consistent nutrient estimates, a uniform procedure should be developed for collecting and analyzing yellow-poplar foliar nutrients. —NE(658).

496. Information on fertilizer application to stimulate early height growth of paper birch and yellow birch regeneration after clearcutting northern hardwoods in New England is scarce. A surface application 4547 Kg/ha dolomitic limestone and 1165 Kg/ha of 15-10-10 NPK fertilizer after clearcutting resulted in a threefold increase in seedling biomass in 4 years. Although large numbers of birch seedlings regenerated in the fertilized stand, pin cherry and shrubs dominated the stand in both numbers of seedlings and above-ground biomass. These results suggest that lime and fertilizer treatments immediately after clearcutting and site scarification may not be favorable for adequate stocking and development of birch regeneration unless pin cherry is controlled. —NE(678).

497. The effect of lime and fertilizers on root development must be known if managers are to effectively improve forest tree growth. In a 90-year-old birch-beech-maple stand in New Hampshire, fine root biomass in untreated plots averaged 1246 g/m^2; after addition of lime, 1229 g/m^2; and after addition of lime and fertilizer, 2711 g/m^2, or more than a twofold increase over no treatment. Biomass increase from soil amendments extended through the soil horizons to all but the C layer. Concentrations and contents of various nutrients increased significantly in the fine roots. These positive consequences of fertilization should lead to a gradual improvement in fertility of the deeper soil horizons and to increased windfirmness, in addition to the immediate benefits to growth and vigor of the forest stand. —NE(677).

498. Currently available apparatus for obtaining small samples of soil air are unreliable or difficult to use in the field. A simple device using porous plastic reservoirs was developed and used in a loblolly pine plantation. Samples obtained from the reservoirs showed CO_2 content of the soil atmosphere followed a gradient from about 0.03 percent at the surface to 1.2 percent at a depth of 60 cm. The porous reservoirs, combined with atmosphere analysis by gas chromatography, provide a procedure whereby soil aeration and other gas-related processes may now be examined simply and quickly. —SE(666).

499. Intensive culture and artificial regeneration change the natural ecosystems of the southeastern coastal flatwoods to promote pine growth. Disking and bedding forest sites in north Florida nearly eliminated saw-palmetto while panicum grasses, bluestems, blueberry, and blackberry became the dominant early successional vegetation. Future ecological research should study the role of saw-palmetto in flatwoods ecosystems so predictions can be made on the effect of widescale destruction of this shrub as a result of intensive forest management. —SE(680).

500. Site index curves are widely used in estimating growth and yield, but some existing site curves often contain weaknesses which are inherent in their methods of preparation. New site index curves have been developed from stem analysis data for loblolly pine in the Atlantic Coastal Plain of the Carolinas and Virginia. These new curves give unbiased estimates of site index that are consistently better than those generated by existing curves. This information should provide landowners with better estimates of the growth potential of their forest lands. —SE(682).

501. More information is needed on the fate of applied nutrients if fertilizers are to be used efficiently and effectively in southern pine forests. In a Mississippi study, young loblolly pine plantations that were fertilized with 112 and 224 kg N/ha as ammonium nitrate produced 25 percent more total above- ground biomass and accumulated 30 percent more nitrogen in 2 years than unfertilized plantations. The pines utilized more of the nitrogen if one-half the fertilizer was applied in April and one-half in August than if all was applied in April, and more if competing vegetation was sparse than if it was abundant. This information will be valuable in developing fertilizer prescriptions for southern pine forests. —SO(659,883).

502. The increasing demand for wood products, coupled with a decrease in available forest land, makes fertilization a potentially useful silvicultural tool for boosting hardwood growth. Nitrogen (N) and nitrogen-phosporus (P)- potassium(K) additions increased diameter and height growth of sweetgum, water oak, and willow oak on clayey Mississippi River floodplain soils by 40 to 60 percent. A single application of 1000 pounds of NPK per acre to eroded soils of the silty uplands increased yellow-poplar heights by 41 percent over a 5-year period. Application of 150 pounds of N per acre increased volume growth up to 200 percent in cottonwood stands established on nutrient-deficient old fields in the Mississippi River floodplain. These results provide fertilization prescriptions which will help the Nation meet its demand for hardwood. —SO(660).

503. Accurate information is lacking on relationships between site quality, total dry matter production, and plant nutrient content. In 19-year-old unthinned loblolly pine plantations in southeastern Arkansas, the ranking of four sites in descending order of total dry matter in boles, branches, and foliage and in quantitites of P, K, and Na in boles was: Coastal Plain poorly drained, Coastal Plain well drained, loess well drained, loess poorly drained. Only drainage influenced quantities of N and Ca in boles: N was higher and Ca was lower on poorly-drained than on well-drained soils. Bark contained 44 to 50 percent of the nutrients in boles. Landowners can now estimate quantities of nutrients removed by timber harvesting on these important forest sites. —SO(668).

504. Dense stands of native grasses reduce survival and retard growth of direct-seeded southern pines on open cutover sites. Mechanical preparation of such sites before sowing about doubled stocking of loblolly and slash pine at age 10 on a silt loam soil in Louisiana. Loblolly pines on flat- and mound-disked strips were 2 to 4 feet taller than those sown in an undisturbed rough. Slash pine growth was not improved. This information will aid landowners in deciding which sites they should prepare mechanically before direct seeding. —SO(669).

505. Growth of slash pine on low sites of the southern Coastal Plain is often restricted by excessive soil moisture. In a Louisiana study, response of planted slash pine to bedding depended upon the increase in average depth to free water during January and February—the period when soil is ordinarily saturated. For each centimeter increase in average depth to water, to a depth of 45 centimeters, stemwood yield at age 8 rose 300 kg/ha and total biomass rose 659 kg/ha. These results will permit landowners to assess the value of bedding prior to treatment. —SO(671).

506. Although bedding and fertilization are popular site treatments in the Gulf Coastal Plains, results are erratic. On

sites where water stands on or near the suface for 8 to 10 months of the year in northwest Florida, trees growing on high beds (10 inches above the normal ground line) were 5 feet taller at age 8 than those on flat-disked ground. On dry and intermediate sites, bedding did not improve tree growth over disking. Top dressing of the wetter sites with 1000 pounds per acre of phosphorus as triple superphosphate at age 2 years improved growth an additional 2 to 5 feet. Forest landowners can now estimate early returns from bedding specific sites. —SO(670).

507. Nutritional balance is generally considered important in the development of seedlings. New information has been developed through a PL-480 grant which relates the effects of potassium, magnesium, and calcium to growth and development of Norway spruce seedlings. Results show that seedlings are very tolerant of media unbalanced in their content of metallic ions, and the concentration of mineral elements in spruce seedlings was highest when its supply was at the highest level and the supply of other elements was limited. These results will be valuable in developing and interpreting fertilization regimes for nurseries in the United States. —WO-TMR(665).

508. Few non-leguminous vascular plants form root nodules, some of which are associated with nitrogen fixing bacteria, an extremely important attribute for maintaining and increasing site fertility. A study of root nodules has identified two non-leguminous types, of which one (alder-type) is associated with nitrogen fixation while the other (podocarp-type) does not appear to be important in this role. However, the podocarp-type nodule enhances the ability of plants to absorb phosphorus which may be valuable for colonizing wastelands where phosphorus deficiency is a limiting factor. —WO-TMR(667,679).

Artificial regeneration

509. Millions of seedlings are now grown in containers, but very limited evaluations have been made of their field performance. A method has now been described for making uniform field comparisons of containerized and bareroot nursery stock and field comparisons are being installed on National Forests in Oregon and Washington. If such studies are made in many areas, enough data can be cooperatively accumulated from which to develop sound guidelines for using both containerized and bareroot seedlings. —PNW(824).

510. The lack of easily-measured maturity indices for cones and seeds of white fir and red fir has often resulted in collections of immature seeds. Research in northern California has shown that white fir cones can be collected when they average about 0.96 specific gravity—usually 3 1/2 weeks before seedfall begins. Red fir cones should not be picked until their specific gravity averages about 0.75, very close to time of seedfall. These guidelines should improve seed quality in collections of these species, thus benefiting nursery and regeneration programs. —PSW(823).

511. Separating tiny seeds from chaff is difficult with small lots of many species. A simple method devised in California shows that small seed lots can be cleaned easily and quickly by decanting the seeds repeatedly from plastic to glass containers. After the plastic container is charged with static electricity by wiping it with a cloth, chaff and empty seeds will adhere to the sides of the container. This method provides a quick, cheap, and effective way for seed handlers to clean small seeds. —PSW(838).

512. Artificial regeneration in Hawaii is difficult and costly with bare-root or bagged seedlings because of the rugged topography and rocky soils. Recent tests with containerized planting stock have shown that polystyrene bullet containers, popular elsewhere, are unsatisfactory for conditions in Hawaii. Planting the bullets was very difficult in typical forest soils. These results will shift efforts to more promising techniques. —PSW(846).

513. More efficient and effective reforestation systems are needed for Hawaii. A Styroblock container system developed in British Columbia appears to meet these criteria for the species and soils of the Islands. Three months after outplanting seedlings of four valuable species, survival exceeded 95 percent for all, and more than 90 percent of the seedlings were growing vigorously. Planting holes were easily prepared with a dibble on a wide range of soils. These results indicate that the Styroblock system can improve Hawaii's reforestation program. —PSW(847).

514. Tree species adapted to infertile, eroded slopes and ridges are needed for watershed protection in Hawaii. At 3000 feet elevation on the Island of Molokai, five pine species from central Mexico have grown vigorously to an average height of 9 to 11 feet in 5 years. These species and four others planted at 6400 feet on the Island of Maui are also growing well. This satisfactory performance gives the Hawaii land manager greater flexibility in species selection for reforestation projects on medium and high elevation sites. —PSW(848).

515. Storage temperatures are an important factor in maintaining healthy planting stock between nursery removal and planting. Comparison of root-mass temperatures between tree packages in culvert or pit snow caches in the mountains of Idaho and Montana and in refrigerated coolers indicated that the snow cache provides better temperature control. Snow storage is cheaper and also appears to provide superior conditions for seedling storage. Guidelines are now available on proper location and installation of snow caches which will enable foresters to successfully store nursery stock on or near the planting site until it is needed for planting. —INT(809,832).

516. Direct seeding has been an effective regeneration method in many regions, but in the Southwest, young seedlings are frequently frost-heaved. Tests conducted under closely controlled conditions (in a chest set in a deep freeze) indicated that frost heaving was directly related to soil bulk density. Several chemicals, such as ferric chloride, calcium chloride, and calcium sulfate, applied at lower non-phytotoxic rates reduced frost heaving in both laboratory and field experiments. Plowing to lower the soil bulk density may be a practical method of reducing frost heaving. —RM(813,814).

517. Spot seeding seems attractive as a possible means of reforesting large areas of mixed conifer forest in the Southwest denuded by fires, insects, and clearcutting. Spots were seeded on three mixed conifer clearcuttings on favorable sites in Arizona, using southwestern white pine and blue spruce, which are adapted to full exposure. After three summers, the seeding was a total failure. Rodents and frost heaving were the major factors. Spot seeding is not promising for reforesting mixed conifer lands in the Southwest. —RM(815).

518. Mulching was tested as a supplementary measure to increase ponderosa pine seedling survival on difficult planting sites in Arizona. Survival of 3-0 spring planted seedlings mulched with clear and black polyethylene, volcanic cinders, woodchips, and dead grass sod was generally unacceptable. Results indicate that mulching is not a satisfactory substitute for complete site preparation careful planting of vigorous stock, and early protection from grazing, fire and competing vegetation. The value of mulches as an aid to survival and growth of ponderosa pine in the Southwest remains uncertain. —RM(827).

519. Mortality of Engelmann spruce planted in high elevation openings is often severe. Research in the subalpine forest zone of Colorado found that intense light at high elevations inhibits photosynthesis of young seedlings and may cause death. When Engelmann spruce seedlings are planted at high elevations, care should be taken to place them only in acceptable microsite such as the north and east side of down logs, stumps, or slash, where shadow offers protection from direct sunlight. —RM(828).

520. A newly developed greenhouse system for growing containerized tree seedlings avoids many problems of outdoor nurseries. In 1 year, greenhouse grown seedlings in North Dakota are equivalent in size to 3-to-4-year-old nursery stock grown outdoors on the Great Plains. This new greenhouse-container nursery will provide better seedlings faster, and over more of the year than the bareroot nursery. This technology will aid the reforestation effort throughout the United States. —RM(839).

521. Geneticists frequently need to root ponderosa pine cuttings in order to obtain plants with the same shoot and root genetic makeup. Recent research has shown that grafting of ponderosa pine cuttings on exposed roots from the tree the cuttings were taken from is much more successful than direct rooting. This technique will be a useful aid to the genetic improvements of ponderosa pine. —RM(840).

522. Widespread interest has developed throughout the United States and Canada in perfecting reliable, economical systems for producing containerized tree seedlings for reforestation. Literature on raising containerized stock in greenhouses is widely scattered. The current status of knowledge on all aspects of containerized planting in North America was reviewed at a 3-day symposium in Denver, Colorado, in August 1974. Of the 90 papers given at the symposium, 33 were authored or coauthored by U.S. Forest Service scientists, specialists, and administrators. The proceedings will be a valuable reference to administrators, educators, and scientists. —PNW(841).

523. Irregularity of good seed crops in many forest tree species requires storage of seed stocks for several years to insure a reliable supply of seed. Recent results in Wisconsin have demonstrated that, with proper storage, viability can be satisfactorily maintained in yellow birch and paper birch seed lots for at least 8 years. The seeds should be kept in closed containers at temperatures of 36° to 40°F. This information will aid nurserymen and others who need to store birch seeds over a period of several years. —NC(807).

524. Heavy mortality of coniferous planting stock is a continuing problem in the Lake States. A systematic evaluation of tree size, packing methods, distribution, location, and planting showed that careless planting is the most important cause of failures of newly planted red pine in northern Minnesota. Distribution procedures and high root/shoot ratios are also problems. Guidelines are provided which could result in much greater returns on planting investments. —NC(808).

525. Large yellow-poplar seedlings are known to survive and grow better than smaller ones in the years immediately after outplanting. Sixteen years after outplanting in southeastern Ohio, yellow-poplar seedlings with original top length greater than 15 inches continue to outgrow those that were less than 10 inches long. Survival of the taller seedlings is also better, and 48 percent have a straight lower bole, in contrast to 26 percent of the short seedlings. Silviculturists can expect to reduce rotations by 3 years when tall rather than short trees are planted. —NC(811).

526. Little is known about the effect of root media on the development of container-grown red pine seedlings. After 16 weeks, seedlings grown in a 1:1 mixture of peat and vermiculite were larger than those grown on eight other mixtures containing two or three of the following materials: peat, vermiculite, arcillite, sand, and loam. The peat-vermiculite mix also possessed the highest cation exchange capacity and retained moisture longest. This information will result in improved containerized red pine planting stock. —NC(825).

527. Mechanical seed counters are commonly used to obtain uniform subsamples of a specific number. A study in Wisconsin, however, has indicated that in jack pine and white spruce seedlots of varying seed size and weight, the use of vibratory electronic counters does not consistently produce representative subsamples. The last few subsamples from a seedlot contained up to 90 percent more empty seeds and weighed up to 70 percent less than the population mean. Awareness of this bias will enable seed handlers to take steps to ensure that samples are representative of the seed population. —NC(829).

528. Survival of planted black walnut seedlings has usually been good, but early growth is typically poor, especially during the planting years. It was recently found that neither planting method nor planting stock treatment had any appreciable effect on survival and growth. The best planting method was the one most convenient for the planter as long as it was compatible with the type of planting stock. Tree planters therefore can use any of several standard planting methods to establish walnut plantations. —NC(849).

529. Unseasonable cold periods may result in major losses of hardwood seedlings in young tree nurseries and in newly established plantations. Many black walnut seedlings growing in a southern Indiana nursery were topkilled by a November freeze. Seedlings fron Kentucky, Tennessee, and Alabama were more seriously damaged than those from Michigan. Seedlings fertilized with ammonium- type fertilizers were less severely affected than unfertilized seedlings or those treated with sodium nitrate. These results are now being used by nurserymen and tree planters throughout much of the Midwest to minimize the risk of cold damage in growing walnut seedlings and in establishing new plantations. —NC(850).

530. Simple, efficient, and effective methods of direct seeding are urgently needed by forest managers in the Northeast to establish white pines on areas heavily occupied by non-commercial species. A furrow seeder was developed from available agricultural equipment that successfully direct seeded white pines behind a fire line plow at a sustained rate of 1 to 4 acres per hour. Costs of the operation were about one-third those of planting nursery grown stock on similar sites. The use of this regeneration technique can help to prevent visual degradation and/or injury to fragile ecosystems. —NE(812).

531. Sugar maple produces good seed crops at irregular intervals which vary from 2 to 7 years. To insure the availability of adequate seed supplies during poor crop years, we needed to know the requirements for long-term storage. It has now been found that sugar maple seeds store best at 10 percent moisture content and at -10°C. This information will help nurserymen better plan their annual seedling production programs and also assist seed dealers in maintaining continuing seed inventories. —NE(851).

532. Intensive culture of fast-growing hardwood species on short rotations may be necessary if the United States is to meet future wood fiber commitments. Scientists from Georgia have summarized intensive cultural practices for the management of commercial hardwood plantations in the South. Using present technology of weed and water control plus fertiliza-

tion, growth of sycamore and cottonwood averages between 3 and 4 cords per acre per year. Results show that practical methods are available for growing hardwoods under several management systems and for different product goals. —SE(801).

533. Authorities disagree on how deep longleaf pine seedlings should be planted. In a Florida study, longleaf pine seedlings (1-0 stock) planted with root-collars at the ground line, were taller, healthier, and more abundant after 5 years than those where the bud was covered with 1 to 3 inches of soil. Thus, deep planting offers no advantage when regenerating longleaf pine on sandhills sites. —SE(804).

534. Sycamore can be established by vertical planting of unrooted cuttings, but cheaper methods of regeneration would be desirable. A recent test of sprouting and survival of horizontally planted sycamore cuttings suggests that large-scale plantings are feasible by this method. The pattern of root development was influenced by number and position of sprouts, by depth of planting, and by cultivation. This technique has the potential to provide a cheaper, mechanized way of establishing sycamore plantations. —SE(752).

535. Reliable methods are needed for vegetatively propagating genetically superior hardwoods for planting in seed orchards and for use in ecological and physiological investigations. Physiologically juvenile 1- or 2-year-old cuttings from individual trees representing ten genera of important southern hardwoods have been successfully rooted using relatively simple propagation techniques. Stump or root-collar sprouts are the preferred source of physiologically juvenile cuttings, but forced epicormic branches from the lower 4 to 6 meters of the bole of mature hardwoods also give good results. The procedure greatly simplifies the task of mass producing genetically uniform planting material. —SE(817).

536. Reforestation programs are normally based on proper selection of seed source, but for some species, elevation of the source has often not been considered. A recent study in North Carolina has shown that northern red oak phenology is highly correlated with elevation of acorn sources. When outplanted at common sites, seedlings from high elevations broke dormancy later than seedlings from low elevations. This information can be used in planting programs to obtain maximum seedling growth and avoid frost damage to low elevation sources. —SE(820).

537. The physiological bases for the competitive advantage of one tree over a neighbor of the same species are poorly understood. Research in Georgia with propagules of fast- and slow-growing clones of yellow-poplar emphasized the important role of early root development in future competition between trees. The shoot/root ratio of these clones also appeared to be under genetic control. This information will help explain certain aspects of competition, and it illustrates the practical importance of clonal mixtures in artificial regeneration. —SE(837).

538. Loblolly pine seeds that have been conditioned for prompt, complete germination by moist chilling must sometimes be stored for a year or more before they are sown. Fully imbibed seeds were stored satisfactorily for 1 year at temperatures between 1° and 15°C. Lower or higher storage temperatures reduce viability. An even safer procedure was to dry the imbibed seeds to 10 percent moisture or less and store them at near freezing temperature. These results will give seed dealers, nurserymen, and landowners additional options for handling stratified seeds. —SO(799).

539. Tap roots of containerized southern pine seedlings frequently grow through the bottom of the container before the trees are ready to outplant. When containerized loblolly pine and longleaf pine seedlings were grown on and off a copper screen base for 1, 2, 3, and 4 months, copper effectively prevented growth of the roots from the tubes and resulted in increased survival at all seedling ages for loblolly pine and with 4-month-old seedlings for longleaf pine. Top growth was not affected. These results clarify the effects of an important variable involved in producing containerized planting stock. —SO(798).

540. Three basic questions to be resolved in developing a reliable containerized planting system for southern pines are tube size, age of planting stock, and planting environments. A Louisiana study in which longleaf, loblolly, and slash pines were grown for 1 and 2 months in 4, 6, and 8-inch long kraft paper tubes and outplanted on disked and unprepared sites revealed that no single combination of treatments was best for all species. Longleaf survival was best with 8-inch tubes planted on disked seedbed. Two-month-old slash pine seedlings survived best. Results will aid scientists in improving containerization techniques for field plantings. —SO(800).

541. Improvements of seed technology for *Quercus* species are hindered by the lack of information on maturation of the acorns. A recent study in central Mississippi has determined physical and chemical changes in maturing acorns of willow, water, and cherrybark oaks. Dry weight of the acorns watered throughout the season increased until physiological maturity was reached in late October and early November. This was also accompanied by a rapid increase in storage foods, fats, and carbohydrates. A number of indices of seed maturity were also identified which can readily be used to improve collection and storage of these acorns. —SO(802).

542. Currently accepted procedures for determining moisture content of acorns are time consuming and error prone. Moisture content of white, chinkapin, Shumard, and water oak acorns was accurately determined by oven-drying the seeds at 105°C after they had been cut into small pieces. The white oak species reached equilibrium in 8 hours; the red oak species in 9 hours. These results provide seed researchers with a more accurate procedure for measuring acorn moisture contents, and should form the basis for modifying International Seed Testing Association rules for determining moisture content. —SO(803).

543. Sandy, droughty sites are virtually impossible to direct seed if conventional methods of site preparation and sowing are used. Retention of a hardwood canopy and covering the seed with soil enhanced establishment of direct seeded loblolly pine on deep, dry sands in Louisiana; but the procedures were unreliable or too costly for operational use. Planting of nursery stock, rather than direct seeding, is the only feasible method of artificially regenerating these severe sites. —SO(806).

544. Site-species relationships must be carefully considered in rehabilitating depleted stands by planting. In 10-year-old planting trials on a variety of sites in Tennessee's Cumberland Plateau and Highland Rim provinces, loblolly and Virginia pines outgrew shortleaf pine, white pine, and yellow-poplar. Loblolly pines averaged 26 feet tall and 4.4 inches in diameter; Virginia pines 22 feet and 3.9 inches; and shortleaf pine 19 feet and 3.4 inches. White pine and yellow-poplar performed poorly. The superior early performance of loblolly and Virginia pines indicates that they should be preferred for planting on narrow ridgetops, degraded sites, and soils having bedrock or fragipans near the surface. —SO(818).

545. Cones of most southern pines are difficult to harvest because they remain firmly attached to branches when the

seed is ripe. An anatomical study of loblolly and slash pine cone pedicels at all stages of development failed to demonstrate the presence of an abscission layer, which negates the probability of inducing southern pine cone abscission with chemicals. —SO(821).

546. Broadcast sowing of southern pines requires large quantities of seed and produces stands that may be difficult to harvest mechanically. A prototype aerial row seeder, which sows three rows of seed simultaneously from a helicopter, was developed and tested. The test identified several problems which must be solved before a reliable operational aerial row seeder can be produced. Successful development of this concept will provide inexpensive and practical means of regenerating forest stands throughout the country. —SO(819).

547. Dense stands of southern pines grow slowly in diameter, which delays the time of first thinning and lengthens the rotation. Studies show that thinning to 500-700 trees per acre at age 3 or 4 years, before live crowns shorten excessively, promotes rapid diameter growth without depressing merchantable volume growth. Mechanical strip-thinning is recommended whenever live crowns of codominant trees drop to 35 percent of totai height. This information will be valuable for managing dense stands of loblolly, slash, shortleaf, and Virginina pine regeneration throughout the South. —SO(791).

548. Planted northern red oak grows so slowly on cutover sites that seedlings may become suppressed by other vegetation within a few years. Weeding increased 3-year diameter growth by about 0.3 inch in two plantations on the Cumberland Plateau. A single thorough weeding was about as effective as repeated annual weeding. Height growth following weeding was reduced by about 0.1 foot per year in a 6-year-old plantation on an average site, and 0.3 foot per year in a 7-year-old plantation on an excellent site. Thus, forest managers can accelerate diameter growth of planted northern red oak by timely weeding with a relatively slight sacrifice in height growth. —SO(831).

549. Since spot-seeding of southern pines often produces clusters of two or more seedlings per spot, foresters want to know how this clustering affects stand growth. In Tennessee, the largest loblolly and Virginia pine seedlings on seedspots had expressed dominance and were 1 to 2 feet taller than their companions at 5 years of age. Moreover, dominant pines on multiple-tree spots were equal in diameter and height to comparable, more widely dispersed trees in broadcast seeded stands. Resource managers may spot seed if they choose, with confidence that stands will not require expensive pre-commercial thinning. —SO(830).

550. It is often desirable to determine if a seed is completely or incompletely developed before it is germinated or tested in other ways. A technique was developed for making stereoradiographs of individual seeds which permit detailed viewing of the seed's contents in three dimensions without destroying seed. The innovation should have broad application in education, industry, and research for detailed examinations of the interior structure of small inanimate objects of any kind. —SO(845).

551. Water oak acorns require cool, moist stratification for prompt germination. How this speeds germination is uncertain. A study of embryos from dormant, stratified, and germinated acorns revealed that stratification greatly increased development of certain organelles, such as dictyosomes and mitochondria. This new knowledge should lead to development of better, more reliable methods of storing and germinating water oak acorns. —SO(843).

552. Intensive culture will be necessary on many sites if the growth of fiber is to keep pace with future demands. A summary paper on southern pine culture is now available which suggests species to plant, site preparation techniques, spacing options, as well as alternative vegetation, water, and nutrient regulation techniques which will maximize fiber yields. This information provides land managers with alternative silvicultural approaches for growing southern pines on short rotations. —WO-TMR(834).

553. In order to supply the latest information on seeds which are the primary means for perpetuating most tree and shrub species, a new 883-page handbook has been prepared which includes seed descriptions of more than 800 species and latest directions for fruit collection, seed storage, and nursery practices. Also included are chapters on general seed biology, genetic improvement, pollen handling, and seed testing. This volume is an excellent reference for foresters, wildlife managers, nurserymen, students, and homeowners.(833).

Stand improvement

554. Thinning mature stands is considered to be of little value because residual trees are not expected to increase in growth rate. A commercial thinning study in 100-year-old ponderosa pine in central Oregon with from 150 to 350 stems per acre showed that losses to mountain pine beetles are reduced substantially when stands are thinned lightly but frequently from below. On good sites, these stands are also capable of growing between 700 and 800 board feet per acre per year from age 100 to at least 130 and probably beyond. Such long rotations are more esthetically pleasing than those less than 100 years because there are larger trees and fewer visually undesirable areas in a regenerating condition. —PNW(761).

555. Public concern over environmental pollution requires that managers use the most sophisticated procedures available for applying herbicides. Many specialized aerial application systems and spray additives have been developed to reduce drift of herbicidal sprays. Brief descriptions of the best available aerial spray systems, additives, and supervision necessary to insure proper use of equipment are now available to foresters. Managers must utilize these improved systems if herbicides are to continue as effective silvicultural tools. —PNW(786).

556. Well-stocked stands of young Douglas-firs are often found under dense overstories of varnishleaf ceanothus in western Oregon, but tree growth is retarded by shrub shade and competition for soil moisture. Aerial spraying with 2,4,5-T effectively released Douglas-firs, and their growth was 1.7 to 2.5 times that of comparable trees under unsprayed ceanothus. Releasing Douglas-firs from varnishleaf ceanothus can conservatively save 8 years in growing trees to a height of 20 feet. —PNW(787).

557. Single applications of herbicides often provide insufficient control of shrub species competing with desirable conifers. One respray of 2,4,5-T applied as an early foliar spray will adequately control resprouting salmonberry, western thimbleberry, vine maple, and California hazel shrubs in the coast range of Oregon. Resprays of amitrole-T or picloram do not appreciably increase degree of control over an initial application. Following these recomendations should greatly improve vegetation control and regeneration potential of difficult forest sites. —PNW(795).

558. More effective treatments are needed to prepare planting sites for reforestation and release conifers from competing brush species on high site lands in the coast ranges of Oregon and Washington. Tests show that mixtures of dicamba

and 2,4,5-T or 2,4,5-T alone are useful for site preparation as budbreak sprays. For conifer release, 2,4,5-T applied in diesel oil was effective on red alder, vine maple, and California hazel. These treatments can be used on thousands of acres of new harvest cuttings and plantations in the Pacific Northwest. —PNW(796).

559. Forest managers badly need even-aged thinning guides integrating site potential, merchantability limit forecasts, cutting cycles, and operable volume limits. Ponderosa pine thinning guides were developed in Idaho for use by foresters in estimating basal areas, stocking levels, and average spacing necessary for fast timber growth. The method appears broadly applicable to conifer forests and will increase thinning returns and improve yield predictions. —INT(788).

560. Conversion of aspen forest types to conifers is difficult because of competition from dense regrowth of aspen suckers. Burning cutover aspen stands at 2 to 4 year intervals reduced the vigor of aspen suckers in Minnesota. Infrequent burning weather, low flammability of the aspen-hardwood association, and prolific sprouting and seeding of shrubs and hardwoods make repeated dormant season burning a poor tool to convert aspen to conifers. However, repeated fall burns may be useful to maintain wildlife habitat if decreases in mountain maple and increases in hazel and willow are acceptable. —NC(792).

561. Clearcutting has resulted in numerous even-aged hardwood sapling stands in the southern Appalachian region, and means are needed to improve stand composition and maintain vigorous growth. Periodic measurements for 10 years after an intensive cleaning in an 11-year-old stand showed that crop trees had 46 percent more diameter growth and 38 percent more basal area growth in cleaned plots than in uncleaned plots. The cleaning influence on diameter growth dissipated between the 6th and 10th years, however, and high initial cost, plus limited growth acceleration, suggest that early cultural treatments should be deferred until commercial stems are available. These data will help foresters decide if early cleanings can be justified. —SE(784).

562. Herbicides applied as foliar sprays to control unwanted hardwoods may drift excessively and damage nearby crops. Thickeners in spray solutions reduce drift, but their influence on effectiveness of herbicides is not known. Mixtures of thickened 2,4-D (Verton 2-D), 2,4,5-T (Verton 2-T),and Tordon K were as effective as conventional formulations of the same herbicides on mixed brush and more effective on certain hard-to-control species such as huckleberry, red maple, and flowering dogwood. Southern landowners can use these new formulations to control vegetation in situations where drift must be minimized. —SO(782).

563. A reliable method is needed for dormant season control of low-value hickories in the mountain areas of Arkansas. When injected at a 1 milliliter rate in continuous incisions or incisions 3 inches apart, Tordon 101 killed virtually all stems within 5 months. With continuous incisions, 2,4-D killed 90 percent of treated stems by the end of the second year. Cacodylic acid (Silvisar 510) and monosodium acid methanearsonate (Silvisar 550) were ineffective at both spacings. These results will help forest land managers in selecting chemicals for timber stand improvement. —SO(789).

564. Because foliar sprays may drift and damage nearby sensitive crops, other methods are needed for controlling unwanted woody plants on forest sites. In the Boston Mountains of Arkansas, soil applications of bromacil and fenuron at manufacturers' recommended rates gave consistent, reasonably high kills of red oaks. Bromacil, picloram, and M-(3,3dimethylureido) phenyl tert-butylcarbamate applied at recommended rates effectively controlled hickories. At one and one-half times recommended rates, all soil-applied herbicides gave high kills of hickory and all except picloram controlled red oak. None were effective at one-half recommended rates. Soil application may be a viable alternative to foliar spraying of herbicides, if higher treatment costs can be justified. —SO(790).

565. There is an extensive area of depleted pine hardwood forests in the Cumberland Plateau of northern Alabama. Nineteen years after improvement cuttings were made, stand volume increased 778 cubic feet per acre on an area where all merchantable low-volume trees were removed in a commercial cut, and 1,498 cubic feet on an area where the commercial cut was supplemented by repeated removal of cull and undesirable trees larger than 2 inches d.b.h. Unmanaged stands grew 237 cubic feet. These findings demonstrate that improvement cuttings in depleted pine-hardwood stands will increase yields, income, and forest land values provided an adequate seed source of desirable species is present. —SO(793).

Animal damage

566. The form of nitrogen used to fertilize seedlings in nursery beds can influence field planting success, especially if chemical composition of seedlings and deer browsing preference are variously affected. In western Washington, shoots from Douglas-fir seedlings fertilized with ammonium sulfate, calcium nitrate, or urea varied little in their chemical makeup, and the trees were equally browsed by black-tailed deer. Results indicate that the source of nitrogen applied in the nursery does not alter field damage from deer browsing. —PNW(728).

567. Sapsucker feeding in northern hardwood forests can kill birch or may slow growth and lower wood quality. A northern Michigan study found that the frequency and intensity of sapsucker feeding activity are related to crown release with the most severe damage being inflicted on the more heavily released trees. Vigorous dominant poles are fed on more often than less vigorous trees, and sapsuckers prefer yellow birch as a summer food source over all other available tree species. These results indicate that valuable sawlog sized birch should not be left along roadways, edges of openings, or isolated in thinned overstories if alternate trees will provide acceptable seed sources. —NC(724).

568. Past attempts to establish black walnut plantations by direct seeding have not been too successful because of rodent depredation. New information refutes a published report that thorough cleaning of walnut seed prior to sowing reduces rodent pilferage. However, sowing in the spring and at a distance of at least 400 feet from mature trees may help reduce predation by squirrels and increase the success of direct seeding for establishing black walnut plantations throughout the Midwest. —NC(726).

569. Regeneration failures in Allegheny hardwoods have frequently been attributed to deer browsing, but this conclusion has been based on very few data. Surveys of vegetation inside and outside deer enclosures on thirteen 5- to 16-year-old clearcuts in northwestern Pennsylvania identified white-tailed deer browsing as the cause of regeneration failures in 25 percent of the areas. About half of the areas successfully regenerated in spite of deer browsing, and other research shows that success rates are much higher if cutting is limited to stands containing abundant advance regeneration. These results clearly demonstrate that deer can be one major cause of regeneration failures in Allegheny hardwoods. —NE(725).

570. Deer browsing is a major factor limiting the success of hardwood planting in Vermont. Several mechanical protective devices were tested in a sugar maple planting of 2-year-old seedlings. None of these devices proved effective. However, the research suggested an alternative to protecting seedlings from deer browsing—using planting stock that is at least 6 feet tall. This approach could make the difference between success and continued failures in hardwood planting. —NE(729).

571. Fall-sown longleaf pine stands are sometimes heavily damaged in the first winter by rabbits that clip and eat the succulent seedlings. These losses can be circumvented by sowing in the spring, if spring germinated seedlings can withstand the harsh summer conditions. In six consecutive years, survival of pines during the first summer averaged only 4.7 percentage points lower for spring than for fall seeding. None of the annual differences were significant. Spring sowing of longleaf pine is feasible and practical where rabbit populations are apt to be high. —SO(722).

572. Although it is known that longleaf pine seeds are eaten by the red imported fire ant, the impact of their predation on the success of direct seeding has not been established. In a Louisiana study, an ant population averaging eight colonies per acre destroyed about one-third of the germinating longleaf seed sown. Damage was only slightly less to seeds coated with bird, rodent, and insect repellents than to untreated seed. Losses were uniformly high within a 20-foot radius of the nests. Populations of fire ants expand rapidly after harvest cutting and site preparation, and should be controlled by standard chemical treatments before southern pines are direct seeded. —SO(723).

Growth requirements

573. Many studies of photosynthesis require carbon dioxide supply systems which will respond to rapidly changing demand. One system utilizes an infrared gas analyzer to monitor CO_2 concentration in a cuvette. Correction volumes of CO_2 can be introduced at 15 second intervals. The equipment can be used by scientists studying photosynthesis where CO_2 concentration is critical. —NE(714).

574. In the Pacific Northwest, Douglas-fir seedlings are preferred deer forage and in many areas intensive browsing seriously retards reforestation. Chemical analyses and *in vitro* digestibility studies of Douglas-fir and other plants collected from Oregon during the winter showed that moisture content, digestibility of tissue cellulose, and overall effects of the plants' water extracts on rumen microbial activity provided the best indications of species preference. These factors could be used in ranking palatability of different plant species and possibly in selection of genotypes or strains of Douglas-fir for browse resistance. —PNW(727).

575. Lack of water frequently limits plant growth, especially in arid regions. Recent control room investigations in North Dakota suggest that water use efficiency of selected plants can be increased by growing them in greenhouses at elevated CO_2 levels. These conditions conserve moisture and suppress photorespiration. Water use efficiency may also be improved through genetic selection. A substantial improvement of plant water use efficiency could increase worldwide production of food and fiber. —RM(718).

576. Knowledge of DNA variation and mitotic cycle time within and among species may make it possible to predict crossability and growth potential. Research in Wisconsin found that DNA quantity per cell in red pine varied by a factor of 2.2 from the lowest to the highest amount in 20 seed sources. DNA quantity was not related to latitude of seed source, as had been the case for some other North American conifers. The mitotic cycle was 24 hours and the period of DNA synthesis was about 19 hours. This information will help basic programs in tree breeding and form the basis for further research. —NC(689,690).

577. The expanding literature on walnut culture and use requires periodic summarization to keep users up-to-date. A newly prepared bibliography of over 220 references dealing with the growth and production of walnut provides a valuable working tool for researchers, land managers, and landowners interested in this fine hardwood. —NC(691).

578. The primary-secondary transition zone in xylem and the sequence of differentiation within this zone are not well understood. Recent research with *Populus deltoides* in Wisconsin shows that the vascular traces originate in developing leaf primordia, and in the primary zone they appear as an aggreation of discrete bundles. As each leaf matures on the shoot, the transition zone advances upward in the internode below. Because leaves are positioned helically on the shoot, the transition zone also advances helically in each internode as it matures. These results are a significant contribution to our knowledge of how wood formation occurs. —NC(703).

579. *Populus* is one of the few genera known to develop both ectomycorrhizal and endomycorrhizal associations, and this ability may contribute to its widespread distribution. In comparing the mycotrophy of five American species of *Populus*, it was found that only two of them can form either endo- or ectomycorrhizae. *Populus deltoides* readily formed both kinds of mycorrhizae, and this is proposed as a primary factor for the diverse growing habitats of this tree species in the United States. —NE(719).

580. In order to develop improved silvicultural systems, better knowledge of basic stand growth relationships is needed. The relationship of stemwood growth to leaf area index was examined in 19 managed stands of yellow-poplar in North Carolina, which had been thinned 6 years previously. Annual volume growth was found to be related to leaf area index. Thinning significantly reduced leaf area but it had substantially recovered within 6 years. These results improve our understanding of stand growth processes in yellow-poplar. —SE(705).

581. The chemical and nutrient content of fruits and seeds of many southern trees and shrubs is not known. Crude fat, protein, total carbohydrates, phosphorus, calcium, and magnesium were determined for seeds and fruits of 26 southern species. Seed of three species had protein contents in excess of 20 percent; eight other species exhibited total carbohydrate content in excess of 25 percent. This information will be useful in assaying the nutritive value of these organs for wildlife and in developing procedures for testing and storing these seeds. —SO(685).

582. Mycorrhiza, the symbiotic association between plant roots and fungi, are of great importance for successful nursery and plantation practices, particularly in afforesting denuded lands. In this pioneering PL-480 study of Indian conifers, fungal mycorrhizal associates are explored and extent of mycorrhizal development in plantations and natural forests is identified. The results will assist materially in improving Indian nursery practices and broadening our general knowledge of mycorrhizae. —WO-TMR(684).

583. The role of detoxification of indole-3-acetic acid (IAA) has been ascribed to IAA-oxidase by some and to its production of oxidation products (which cause characteristic auxin-type physiological responses) by others. A PL-480 experiment

in India using bean hypocotyls supports the hypothesis that enzymatic oxidation of IAA is essential for a positive growth response and refutes the detoxification ascribed to IAA-oxidase. —WO-TMR(693).

584. Peroxidase isoenzymes are important in plant growth and differentiation, including initiation of roots. Two specific isoenzymes (a and b) associated with root initiation have now been identified in bean plants along with another (cycloheximide) that appears to inhibit initiation. These results were obtained through an Indian PL-480 grant, and improved our ability to vegetatively root plant species. —WO-TMR(694).

585. Alternative right- and left-oriented domains occur in the vascular cambium of trees and are reflected in oblique anticlinal divisions and other growth structures. PL-480 studies with sycamore show that these domains appear during formation of the first annual ring, and their arrangement is related to stem division into nodes and internodes. These findings have expanded our basic knowledge of the process of wood formation. —WO-TMR(701).

586. Natural gibberellins (GA) apparently play a vital role in the formation of adventitious roots on willow cuttings, but the sites of synthesis of these gibberellins are not known. Studies with girdled and debudded willow cuttings at Kornik, Poland, have shown that free and bound gibberellins occur in both shoots and adventitious roots, but not necessarily the same type of gibberellin. Both tissues are sites of synthesis, and both influence the quantity and quality of GA formed in each other. These results on sites of GA synthesis will aid research efforts on vegetative propagation and the physiology of root growth. —WO-TMR(702).

587. Scotch pine, one of the world's most important timber species, is relatively slow growing during its first 2 years of development. Researchers at Copernicus University in Poland found that, during intensive growth in a seedling's first 7 or 8 days, the level of free gibberellins was high and that the level of abscisic acid-like inhibitors was low. As growth slowed after 8 days, gibberellins decreased, and abscisic acid-like substances increased. Knowledge of the interrelationships of natural inhibitors and promoters will help all research programs involved in basic studies of seedling growth. —WO-TMR(706).

588. Phenolic compounds are known to play essential roles in the processes of plant growth and development, but their relationship to endogenous plant growth regulators is not clear. Supported by a PL-480 grant, scientists in Poland have recently shown that vanillin and p-coumaric acid applied to young Scotch pine seedlings both stimulate growth. The growth stimulation coincided with an increase of auxins and with a decrease of free gibberellins in the seedling roots. Free gibberellin levels increased in the shoots. These data provide new information on the role of growth regulators in woody plants, and will help Forest Service researchers toward their goal of optimizing seedling growth. —WO-TMR(707).

589. Effectiveness of externally applied auxins in stimulating rooting of stem cuttings varies with season. Studies with *Impatiens* cuttings suggest that these seasonal variations are associated with changes in levels of endogenous auxin which, in turn, are a consequence of temperature. This basic information, developed through a cooperative PL-480 grant to India, should assist in improving our ability to root vegetative materials. —WO-TMR(712).

590. The effects of nucleic acid and protein synthesis inhibitors on root initiation are not well known. New information developed through an Indian PL-480 study of *Impatiens* hypocotyls shows pretreatment of cutting with such inhibitors breaks basal dominance resulting in root emergence all over the hypocotyl surface rather than simply at the base. This research could be broadly applicable in reproducing difficult-to-root plant species. —WO-TMR(710).

591. Variability in rooting presents problems where vegetative propagation is to be employed. Research at Panjab University in India under the PL-480 program has shown that a proper balance between auxins and nutrition is necessary for optimal production of adventitious roots on *Impatiens balsamina*, and that this balance varies with the morphological nature of the cutting and with various environmental factors. Endogenous levels of auxins apparently exert a strong influence on the amount of IAA which is needed to stimulate root formation. This information contributes to our basic knowledge of the physiology of rooting. —WO-TMR(711).

592. Proper balance between auxins and nutrients is necessary for root initiation. A PL-480 study of isoenzyme patterns in poplar suggests a complex pattern of repression and synthesis of specific isoenzymes is associated with root initiation. Cycloheximide, which is considered to be a potent inhibitor of protein synthesis, actually induces or activates some new indolylacetic acid-oxidase isoenzymes. Results should lead to a better understanding of auxin roles in tree seedling development. —WO-TMR(1020,1021).

593. It is well known that auxins play an important role in the formation of callus tissue and adventitious root on poplar cuttings, but the mechanism of this action at the cellular level is largely unknown. Results from India have suggested that the amount of rooting is partly determined by the size of the protein and nucleic acid pools available in the tissue at the time of root initiation. The balance between auxins and the carbon pool influences both root formation and callus formation, but not in the same manner. These studies will help our research efforts on vegetative propagation of forest species. —WO-TMR(709,713).

594. Rapid progress is being made in our understanding of the factors affecting forest biology relationships, but the information is often scattered throughout scientific literature. A recent biennial symposium on forest biology included more than 40 papers from Forest Service scientists documenting "state-of-the-art" knowledge and ongoing research in such fields as forest tree nutrition, photosynthesis; growth analysis, developmental morphology, auxin relationships, moisture requirements, and tissue culture. The proceedings of this symposium provide a valuable reference tool for forest biologists concerned with fundamental aspects of forest tree growth. —PNW(716).

595. Increased knowledge of the growth of shoot apices of gymnosperms could help answer basic questions on tree growth. Recent studies in India under the PL-480 program have described major trends of specialization in shoot apices of many gymnosperms. Comparisons were made with the economically important conifer families, as well as other gymnosperms. —WO-TMR(715).

596. Seeds of the oaks are among the most difficult to store of all tree seeds. Research in Poland has indicated that the level of activity of the enzyme alpha-amylase in northern red oak is a good indicator of the general physiological state of the acorns. Amylolytic activity rapidly decreased in acorns stored at -3°C, to a level of no detectable activity after 8 months. These data provide valuable insights into physiological changes in acorns, and will aid in developing improved methods to maintain seed viability in long-term storage. —WO-TMR(717).

597. Differential response of cambium to auxin has been proposed as one cause of reaction wood. Effects of several

vitamins and chemicals which regulate cell metabolism in combination with indolylacetic acid were investigated using Scotch pine stems. Auxin did not affect cell walls advanced in differentiation, but proved essential in completing tracheid ontogenesis. Results from this PL-480 grant have increased our basic understanding of wood formation. —WO-TMR(720).

Growth and yield

598. Loblolly pine grows well in Hawaii, but data to suggest optimum plantation spacing are needed. Measurements in plots on the Island of Maui showed that, 11 years after planting, the wider spacings continued to produce substantially larger average diameters, but less total basal area. Average diameters ranged from 6.4 inches at 6-foot spacing to 9.8 inches in the 12-foot spacing. Basal area was 168 square feet per acre at 12-foot spacing and 278 square feet at 6-foot spacing. The results will help selection of spacings on medium quality sites for various management objectives. —PSW(862).

599. Although white spruce makes up less than 4 percent of the volume of all growing stock in Black Hills forests, some white spruce stumpage is sold. Tables and equations are now available which permit estimation of total and merchantable volumes in cubic feet. Total volumes include all stemwood from ground line to tip of tree, while merchantable volumes include stemwood from a 1-foot stump to a 4-inch d.i.b. top. Data will permit managers to evaluate and equitably market white spruce. —RM(852).

600. Under present utilization standards, many of the Nation's fine hardwoods, such as black walnut and yellow-poplar, have little or no value if they are smaller than sawlog size, resulting in considerable waste when immature stands of these species are thinned. Small diameter trees removed during thinning operations in southern Illinois were successfully converted into furniture dimension material. As much as 2000 square feet per acre of 1-inch material suitable for manufacture into furniture can be produced from intermediate thinnings. Use of thinning residue for dimension material could increase the supply of all lumber grades and help conserve the rapidly dwindling supply of high-quality hardwoods. —NC(855,859).

601. Control of stand density through thinning is one of the most feasible ways of achieving many objectives of forest management—if the response to thinning is known. Data from 141 natural yellow-poplar stands in the Appalachian Mountains of Virginia, North Carolina, and Georgia have provided equations which describe growth and yield in response to thinning. Maximum board-foot and diameter growth were obtained at considerably lower densities than needed to produce maximum cubic-foot volume. These guidelines should prove valuable to resource management making decisions on treatment of natural stands of yellow-poplar. —SE(853).

602. The biological potential for forest ecosystems is needed to determine availability of timber now and in the future. For the loblolly pine ecosystem on 12.4 million acres in the Southeast it was estimated to be 1.2 billion cubic feet of net annual growth per year. To achieve this biological potential, the most important action programs should be to assure the reforestation of every harvested loblolly pine to full stocking. A most important research effort should be to find inexpensive ways to rapidly reforest harvested loblolly pine stands. —SE(854).

603. Projected demands for pulp and paper products indicate an important need for methods of increasing productivity on forest lands. Yields and other stand data from two coppice plantations of sycamore in Georgia have indicated a potential threefold increase in wood fiber production over conventional regeneration and management methods. Spacing of 4 x 4 or 4 x 6 feet should be favored for 3- to 5-year cutting cycles. This short-rotation coppice method could lead to significant increases in fiber production, and it may be applicable to other species and regions. —SE(857).

604. Little is known about growth rates of longleaf pine plantations under varying intensities of management. In an unthinned east Texas plantation, where site index averaged 83 feet at 50 years, merchantable yields at age 25 ranged from 18 to 45 cords per acre, and increased with increasing basal area. Periodic annual growth after thinning increased directly with residual stocking and exceeded 2 cords per acre if basal area was greater than 70 square feet. Diameter and volume growth of individual trees declined as initial diameter of the tree and basal area stocking increased. Equations were developed which predict growth rates of individual trees and stands. This information will enable landowners to select residual densities for longleaf pine plantations that best fit their management goals. —SO(858).

605. Resource managers need accurate information on expected yields of southern pine plantations to guide them in deciding when to harvest planted stands and whether or not to establish new plantations. Growth models and yield tables were developed for loblolly and shortleaf pine plantations in the Tennessee, Alabama, and Georgia Highlands which show expected cubic-foot yields, basal area, height, and trees per acre by 1-inch diameter classes for likely combinations of planting density, site index (base age 25 years), and age from seed. —SO(860,861).

Forest measurements

606. Existing cubic-foot volume tables are inadequate to accurately predict growth in young Douglas-fir stands. Stem analysis data were gathered from Oregon, Washington, and British Columbia and two volume equations derived. One equation is for trees 6 to 18 feet in height and has a data base of 59 trees. The other equation is for trees larger than 18 feet in height and has a data base of 1068 trees. Volume tables were prepared from these equations using a new technique that will insure managers close and consistent estimation of cubic-foot volume of small trees. —PNW(866).

607. Some foresters anticipate the change to metric measurement as a potential disaster. A recent paper presents history of the metric system and metrication in other countries. Results should reassure the previously uninformed that all we face is an easier and more efficient measurement system. —PNW(865,877).

608. Douglas-fir has a different height growth pattern in high-elevation Cascade Range forests than that shown by existing site and yield tables, all of which are based on low elevation stands. For a given height at age 100, early growth is slower, and growth is sustained to greater ages at high elevations. Thus, yield estimates derived from low elevation stands are not applicable. New site index curves derived from stem analyses of 52 trees provide a more accurate basis for Douglas-fir site classification and growth prediction at high elevations in the Pacific Northwest. —PNW(869).

609. Conventional site index curves may not always be the most efficient method of estimating tree height-age relationships. Regressions of height on age and site index on height and age, derived from noble fir, Douglas-fir, and red alder stem analysis data in the Cascade Mountains of Washington and Oregon, showed significantly different curves. It is concluded that conventional curves having height as the depen-

dent variable should be used to construct yield tables. Curves having site index as the dependent variable should be used when the purpose is to estimate site index or future height from measured present height and age. —PNW(868).

610. Spatial distributions of redwood seedling and sprout regeneration are different and require different sampling methods to estimate stocking. A combination sampling method of milacre quadrats for seedlings and point-samples for sprouts was proven successful in a clearcut old-growth redwood stand in northern California. The variation in estimates of the number of sprouts per acre by point-sample was much less than variation in estimates by quadrats. An estimate of future sprout stocking was made by assuming a crop tree from each redwood clump and then comparing estimated number of crop trees per acre with yield tables. This technique allows improved estimates of stocking for the future forest crop. —PSW(872).

611. Statistically-rigorous procedures for modeling probability of mortality for individual trees have not been available to forest researchers. A mathematical problem-solving rule from the biomedical field has been adapted to forestry use by introducing techniques to handle data sampled with unequal probability. In addition to modeling probability of tree mortality, the procedure has also been used to predict the presence or absence of cull in trees and to investigate the levels and trends of natural inactivation of white pine blister-rust cankers. This procedure can be applied to other situations in which the response to be predicted is dichotomous. —INT(871).

612. Interest in and probability of adoption of the metric system has created a need for expressing forestry measures in metric units. Existing tree volume equations for major Rocky Mountain and Southwestern species have been converted to metric equivalents. A simple procedure for converting any tree volume equation of the form V .. a - b D^2H has also been developed. This research will help foresters become accustomed to familiar relationships in metric units and start adapting computer simulation programs and other management tools to their use. —RM(873).

613. Foresters often need to know the size of individual trees which have been removed from cutover stands. If precutting measurements are lacking, key dimensions of missing ponderosa pine trees can be estimated using new aids. In the Black Hills of South Dakota, tables and equations permit direct estimates of diameter at breast height, outside bark, from inside and outside-bark diameter of stumps 0.5 and 1.0 foot high. If stem volumes are needed, heights of missing trees can be estimated by determining the diameter-height relationship for trees in the immediate vicinity. —RM(876).

614. Prediction of growth under various stand and site conditions is a prerequisite for knowledgeable management. Multiple regression techniques were used with data from thinned stands of yellow-poplar in North Carolina to relate growth of individual trees to several readily measured parameters of tree and site. The best equations accounted for approximately 50 percent of the variation in diameter growth. Of the competition indices tested, none proved substantially better than average basal area per acre. These results will aid in further studies of stand growth and how its measurement may be improved. —SE(863).

615. Because chips from slabs and edgings are valuable byproducts of modern sawmills, methods are needed for estimating volumes of these residues in logs and standing timber. The International and Scribner log rules have been adapted to estimate kerf and slab-edging volumes as well as lumber volume in logs. As reliable taper curves become available for individual species, the technique can be used to construct volume tables and compute yields per acre of lumber, slabs, edgings, kerf, and topwood. —SE(864).

616. Processing of mensurational data collected using different sampling systems and measurement techniques is a continuing problem. An improved program is now available for using dendrometry data from individual or clusters of trees selected by means of a variety of sampling designs to provide estimates of volume, surface, length, product, and value. The use of this Georgia research will result in more efficient processing of large amounts of data used in forest inventory and timber appraisal. —SE(870).

617. Whenever predictor variables in a regression analysis are highly correlated, regression coefficients determined by the process of least squares are unreliable. New research extends the techniques of ridge regression so that prior information on parameters can be accommodated. Estimators are unbiased if the prior information is unbiased. The techniques given have potential application whenever regression analyses are conducted in the presence of prior information on the regression coefficients. —SE(874,875).

Management planning

618. Good resource management decisions require sound quantitative data from the management unit. Manual extraction of this data from photographs and maps is slow and expensive, but computerized mapping offers a greatly improved system for this task. A recent comparison of manual and automated digitizing procedures suggests that investment in automatic map digitizing hardware will substantially reduce data collection costs per acre for a large workload. The gains from such a geographic information system offer forest managers expanded and improved bases for management decisions. —PSW(879).

619. Natural catastrophes, such as wildfires, create sudden changes in forest conditions. Forest type, location, and boundaries must then be replaced with new information. A new method of acquiring locational information has been tested on the Stanislaus and Eldorado National Forests in California. This computer-based system permits easy maintenance of a current data base and avoids the necessity of acquiring completely new data periodically. —PSW(884).

620. Height increment is difficult to measure accurately on standing trees; however, it is a major component of forest growth calculations that are needed for timber management planning and reviews of timber resources. Directly measured height increments on 1,185 felled trees were analyzed to develop prediction equations based on tree height, diameter, and radial increment for 10 species of trees growing in 10 habitat types of the northern Rocky Mountains. These prediction equations will assist managers in estimating forest growth and yield. —INT(887).

621. Large areas of old-growth spruce-fir forests in the central Rocky Mountains are being converted to stands that must be managed from the regeneration period to harvesting. To assist in making management decisions in this region, a new computer program, SPRYLD, has recently developed which can produce yield tables for managed even-aged Engelmann spruce-subalpine fir stands at a cost of only 8 cents each. Large numbers of tables can be computed based on combinations of site quality, frequency and intensity of thinning, regeneration system, rotation length, and utilization standards. With the new computer program, a manager can examine a set of yield tables to assess probable results of his proposed

operations and make necessary changes in management goals before operations are carried out in actual forest stands. —RM(878).

622. Land managers and land use planners must know the available multi-resource options and the long term consequences of decisions made on forest areas. A model has been developed for the central Rocky Mountains which simulates timber yields and determines changes in snowmelt and water yield resulting from harvesting timber. Hydrologic changes and timber yields can be determined for a few years or an entire rotation of subalpine forests (120 years or longer). Land managers now have a decisionmaking aid that can be used to project probable changes in snowmelt, water yield, and timber growth and yield following timber harvesting in lodgepole pine and spruce-fir forests. —RM(881).

623. Many systems designed to provide information useful in land-use planning or resource management are not cost-effective because it has not been clear just how the information is to be used. A recently described decision framework for management provides new guidelines on how the information should be used. The new decision framework suggests that inventory system designs should carefully specify objectives, consider the value of information in the sense of losses incurred as a result of inadequate information, and be aware of advanced principles and current alternatives. Both land managers and inventory design specialists can use this framework to be more cost-effective in designing resource inventory systems. —SE(889).

624. Resource managers and inventory designers are continually facing rapidly increasing costs of information gathering, increased demand for resource stock and productivity information, and alternative approaches to inventory. A systems-analytic assessment of: (1) Information needs; (2) properties of sample selection rules, estimators, and measures of reliability; and (3) cost effectiveness analysis of alternative sampling schemes has been proposed. Examples of such assessment relate to equal and unequal probability, 3-P sampling, sampling with partial replacement, and other sampling schemes which might be used for simultaneously estimating growth and current inventory. Results will assist inventory designers to control costs of obtaining information of required reliability and to assess this reliability. —SE(888).

625. Accurate and comprehensive information on natural resources is essential for rational land-use planning. The Puerto Rico Natural, Cultural, and Environmental Resources Inventory used black and white aerial photography, simple photo interpretation techniques, and a computer program to develop a data bank from which information can be retrieved by conventional overlays, computer-drawn maps, or tabular outputs. The data bank can easily be expanded or updated as additional, more complete, or more accurate information becomes available. This method can be used by government agencies and private groups for overall land-use planning, as well as for a variety of immediate practical projects. —ITF(882).

Maple syrup production

626. Both parental and clonal stocks are needed in a program for the genetic improvement of sugar maples for sap-volume production, to assist maple syrup producers in satisfying the increasing demand for their product. Phenotypic selections were made among sugar maples in eight of the important syrup- producing States. In the first year of the program, 55 superior sap-producing trees out of 2,375 tested were found that have potential as parent stock and clonal material in the improvement program. —NE(947).

627. The lack of an easy method of comparing sap volume production between trees has long stymied phenotypic selections of sugar maples for superior sap volume production. In recent research in Vermont, high correlation has been found between sap-flow rate and total sap volume produced during the sugaring season regardless of whether trees were single- or multi-tapped. Measurements of sap-flow rates in conjunction with other parameters can now be used in developing criteria for making plus-tree selections for super sap volumes. —NE(949).

Naval stores

628. In the last few years, a number of improved, modern methods have been developed to benefit both the gum producer and the timber owner. These are now described in a new booklet which details recommended procedures for maximum gum production. By following the various recommendations, chipping-labor requirements can be reduced by 50 percent and many otherwise worked-out trees can be made salable for other wood products. —SE(951).

629. Removal of the rough outer bark of slash and longleaf pine prior to oleoresin collection is a difficult and time consuming job. A rossing tool powered by a lightweight chainsaw motor has now been developed, which prepares a smooth seat for attaching tins and cups and makes chipping of streaks easier for the workers. The motorized tool is practical and readily adaptable to woods conditions in the average commercial naval stores operation. Mechanical power eases the hard physical work of rossing trees and is 60 percent faster at the tree than the handtool; man-day accomplishments are substantially increased. —SE(953).

630. Successful use of acid paste to prolong gum flow requires application of the correct amount of paste to freshly chipped streaks. A new stainless steel tip has been developed to add to the nozzle of acid paste bottles which improves the efficiency of the acid paste. Because workers will not be able to ream out or enlarge the steel opening, the new tip should help prevent overtreatment and should last a minimum of 1 year. —SE(952).

631. Mechanical wounding and chemical treatments are commonly employed to stimulate oleoresin production of southern pines. Recent studies of wood around resin chipping wounds showed an increase in the abundance of tyloses, which are outgrowths of the parenchyma cells into a tracheid cavity. An exception was paraquat treatment which appeared to restrict tyloses formation. Tyloses in pines are not common, and this appears to be the first such report of tyloses in stemwood of pines with pinoid pits. —SE(954).

Breeding Improved Trees

Inherent variation

632. Selection of zones for provenance trials and plantations can be inefficient if based on trial and error. Data from an extensive Scotch pine provenance test in Sweden were used to develop a model based on the concept that species developmental cycles should match seasonal cycles for adaptation in high latitudes. The model indicated that the area suited for plantation zones for Scotch pine on severe sites may be only 5-10 percent of the area suitable for plantations on mild sites within the same geographic region. This information can be extremely useful in the planning and interpretation of provenance trials in the northern U.S. —PNW(892).

633. In cases where local seed is not available for regeneration programs, the limits to which non-local sources may be used should be known. Research in Oregon with 44 provenance collections of Douglas-fir from the Northwest used models to predict timing of vegetative bud burst in seedlings. The prediction equations suggested that moving seed in east-west directions is likely to be more maladaptive than moving seed an equivalent north-south distance. These results can aid decisionmaking in regeneration programs where seed source is a vital question. —PNW(891).

634. Ponderosa pine in California grows on a wide variety of soils ranging from highly infertile, ultramafic soils, to highly fertile, granitic soils. Seedlings of selected, wind-pollinated ponderosa pine showed large between-family differences in growth and survival on infertile soils. The families showing the greatest growth were more efficient in taking up calcium, the element in which ultramafic soils are characteristically deficient. These results clearly show that only ponderosa pine families with proven adaptation to specific soil conditions should be used in reforesting infertile soils. —PSW(898).

635. Accelerated artificial regeneration of Douglas-fir in the northern Rocky Mountains requires an expanded knowledge of patterns in genetic variability for use in delimiting seed zones. New data indicate a high degree of variability in Douglas-fir populations in this region. Populations are not systematically differentiated by topography (drainage, slope, and aspect), but are correlated with broad geographic areas and with specific habitat types. The valuable conclusion for foresters is that seed zones can be more accurately defined and yet broader than previously anticipated. —INT(906,907).

636. Aspen clones growing side by side often show substantial height differences which may be an important selection criterion. Height over age curves of dominant trees were compared for five pairs of adjacent clones by destructively sampling 70-year-old aspen stands in Arizona. Height growth differences between clones at age 30 or younger may sometimes be reversed. Aspen planting programs should take advantage of clones with superior growth potential as well as other inherent differences, but clonal material should ordinarily be collected from stands over age 30. —RM(816).

637. It is possible that there are strains or races of ponderosa pine from sources outside the Black Hills which possess traits making them superior to local growing stock. Seedlings representing 75 provenances in the eastern portions of the species' range were planted on the Black Hills Experimental Forest. After 5 years on a better-than-average site, no trees from other provenances survived better or grew taller than comparison trees from the Black Hills. Trees from some sources in Wyoming, eastern Montana, Nebraska, and North Dakota showed enough promise to warrant continued study, and perhaps more widespread testing. In time, some of these trees may reveal characteristics of growth, quality, or pest resistance which would make them desirable for breeding and propagation. —RM(914).

638. Selection of suitable geographic seed sources is the first step in a tree improvement program. In one Maryland planting, local black walnut seedlings were taller than those of 12 out-of-state sources after 5 years. Genetic influence on height growth was expressed early with little change in ranking after the third year. Seedlings from south-of-local sources outgrew trees from northern sources indicating that seedlings originating north of Maryland should not be used to establish plantations in that State. —NC(903).

639. Genetic improvement in forest trees is a slow process due in part to the long time required for selected progeny to mature and produce seeds. In a recent study on the Allegheny National Forest in Pennsylvania, it was found that nitrogen and phosphorus fertilization stimulated early flowering of black cherry seedlings in a 2-year-old seed orchard. Growth was also increased, suggesting that, by proper fertilization, the time required for black cherry to produce seed can be greatly shortened. —NE(894).

640. Interspecific hybridization can provide the wide diversity of genotypes needed for maximum genetic improvement with trees. The genus *Populus* offers far greater possibilities for genetic improvement than any other genus of forest trees because of the diversity of the genetic resource, species crossability, possibility of clonal propagation, simple controlled breeding methods and other factors. Poplars can be bred to order for timber and veneer production, fiber crops, or amenity plantings. —NE(911).

641. Early selection is an important factor in any tree improvement program. With hybrid poplar clones grown in New England, early selections based on total height at 1 or 4 years may result in negative selection differentials at age 15. These results suggest that when genetic correlations between early and mature performance are low, a reduced selection intensity may be the only way to preserve the best clones at age 15. —NE(918).

642. Tree improvement efforts in the Southeast have as their goal the production of rapid-growing, disease-resistant trees with straight boles and compact crowns. To examine the effects of these efforts, 10-year-old trees from a heritability study of loblolly pine were chosen to represent extremes of stem straightness, branch size, and disease incidence. Results indicate that wood from straight, small-limbed trees yields significantly more pulp of greater resistance to tear than does wood from crooked, large-limbed trees. Fusiform rust-infected wood yields significantly less pulp with lower burst and breaking length than does rust-free wood. —SE(890).

643. Slash pine is one of the most valuable of the southern pines and a species in which genetic improvement is rapidly taking place. For example, major emphasis of range-wide slash pine improvement programs is on improving growth rate, tree form, oleoresin yield, and resistance to fusiform rust. Other efforts are directed toward improving seed quality. The state of genetic improvement as well as the distribution, taxonomy, pollination, techniques, growth, and survival rates are now summarized and evaluated for those planning to use this species. —SE(893).

644. Outstanding individual trees of *Eucalyptus robusta* introduced into Florida before the turn of the century have potential for timber production, even though volume growth of average trees is marginal for industrial pulpwood plantations. One generation of selection within 57 open-pollinated families in a species introduction arboretum produced a 68 percent increase in volume of individual trees. The eventual conversion of the progeny test into a seed orchard will provide genetically improved seed to the public for planting on acid flatwoods and dry prairies of south Florida. —SE(895).

645. Most pine breeding programs in the South are currently based on phenotypic selection of individual trees of only local origin. New provenance research results in Georgia with loblolly pine at 15 years of age indicate that tree breeders throughout the South should increase their emphasis on geographic variation to obtain additional gains from individual tree selection. Selections should be made among provenances first and than among mother trees within provenances. —SE(901).

646. Forest tree geneticists usually assume that the genetic correlation among offspring from an open-pollinated tree is .25, but this assumption may cause bias in estimates of heritability and genetic gain. A recent analysis of this problem using a range of hypothetical conditions suggests that correlations under real situations will usually be appreciably larger than .25. In most forest tree populations, the use of .25 as the correlation will result in a net overestimate of genetic variance and heritability. An awareness of this bias can help the planning and operation of tree improvement programs. —SE(912).

647. New studies with cottonwood indicate that, with the exception of first-year height, predictions of genetic growth response from single sites were not widely different from predictions based on three sites. Genetic gains that can be obtained are 9 percent for height, 21 percent for diameter, and 8 percent for specific gravity. Estimates of genetic parameters will be useful to cottonwood breeders, and the gain in growth can be utilized by commercial growers. —SO(905).

648. Seed production is of primary importance to the success of tree improvement programs. Considerable disagreement exists in the world literature as to factors that enhance seed production in conifers. A recent synthesis shows that most observed responses can be explained on the basis of enhanced nitrogen availability at the critical period of strobili initiation. Yet, genetic control of fruitfulness is crucial, and must still be considered in planning future experiments. —SO(910).

649. Grafted pines have been used in the past to evaluate the inheritance of cortical terpene composition without any real knowledge of possible rootstock effects on terpene composition. Scions of three loblolly clones were grafted on five southern pine rootstocks. Gas chromatographic analysis of scion cortical monoterpene showed a neglible rootstock effect with clonal effects being large. Thus, current estimates of heritabilities based on grafted pines are essentially accurate. —SO(909).

650. Determination and preservation of natural genetic variation in tropical and subtropical tree species is urgently needed, before the existing wild stands are destroyed. In a study of 16 *Pinus caribaea* provenances in Puerto Rico, the mean hypocotyl lengths of newly germinated seedlings were found to be statistically different. These differences apparently represent true genetic variation. Such traits may be useful in detecting genetic variation between provenances of this species. —ITF(915).

651. The tree breeder and forest geneticist need a broad general knowledge of the taxonomic relationships, reproductive behavior, and genetics of tree species they are working with. Information on these essential characteristics and extent of breeding and tree improvement programs are now available for five important species—Sitka spruce, blue spruce, pitch pine, Virginia pine, and chestnut. These syntheses should prove of major value in development of tree breeding efforts. —WO(896,897,900,902,908).

Insect-disease resistance

652. Leaf rust can seriously limit yields of poplars grown under intensive culture for pulp. Plantings of poplar clones at Rhinelander, Wisconsin, have shown that *Melampsora medusae* leaf rust may be a threat to maximum fiber production because it reduces the photosynthetic area of leaves and causes premature defoliation. Out of 32 different *Populus* clones tested, degree of resistance varied from total resistance to severe susceptibility. Thus, candidate clones of poplar should be screened for rust resistance early in the selection process, and such resistance incorporated into clones selected for propagation. —NC(501,921,924).

653. Southern pine seed orchards are not producing nearly as much improved seed as they could. Recent studies in the South indicate that less than 25 percent of the potential seed production is being obtained. Good gains could be achieved by better control of the insects which feed on seed. A reasonable goal for seed efficiency is 80 percent for seed orchards with adequate insect controls. —SE(919).

654. First-year conelet abortion in southern pines may reduce the potential crop of mature cones 50 percent or more. Pollen deficiencies and the feeding of seedbugs are major causes of abortion. Feeding on ovules by seedbugs in spring and early summer causes much of the conelet abortion in seed orchards previously attributed to inadequate pollination. Recognition of this fact should stimulate much needed research to develop methods for controlling these important seed insects. —SE(923).

655. Tree hosts for the large 1963-66 epidemic of the Scolytid, *Dendroctonus frontalis* Zimm., in Honduras, C.A., have now been morphologically confirmed as *Pinus oocarpa*, *Pinus caribaea* var. *hondurensis*, and *Pinus tenuifolia*, and not *Pinus pseudostrobus* as heretofore supposed. Little or no hybridization between the three pines was observed. Xylem oleoresin monoterpenes were useful for differentiating among host species, but no consistent terpene differences were found between supposedly beetle-resistant trees and check trees of each species. —SO(920).

656. Artificial inoculations are used to identify loblolly and slash pines resistant to fusiform rust. A technique employing suspended telia-bearing oak leaves has been used widely, but it and other available methods lack the flexibility necessary for automation as well as control over inoculum density and source. A more efficient spray technique has been developed, and results with it correspond closely to those after exposure via the oak leaf technique. This agreement, and its greater flexibility in terms of inoculum source and density as well as its ease of automation, qualify the spray-inoculum source technique for use in large-scale resistance breeding programs. —SO(922).

657. Selection of fusiform rust-resistant pines in the southern United States has been greatly aided by the development of artificial inoculation techniques. Samples of loblolly pine seedlings from Arkansas, Louisiana, and three places in Alabama were artificially inoculated with fusiform rust at ages 6 weeks and 1 year, and then planted in southeastern Louisiana and central Mississippi. Progenies ranked the same in terms of field infection as when artificially inoculated at age 1, but artificial inoculation of 6-week-old seedlings resulted in heavy infection, largely obscuring genetic differences among progenies. Control of inoculum density seems a necessity if artificial inoculation of 6-week-old seedlings is to be a reliable indicator of field performance. —SO(925).

Tree breeding methodology

658. Douglas-fir grafts in two Oregon and two Washington seed orchards were leader-pruned for six successive years to find out if height could be desirably controlled without reducing cone production. Results indicated height growth control reduced cone production in direct proportion to reduction in tree height. In order to provide a large crown surface for cone production, it is recommended that trees be permitted to grow at least 15 to 20 feet tall before annual or biannual pruning is started. —PNW(932).

659. Grafting is an essential technique in Douglas-fir tree improvement; however, Douglas-fir commonly rejects grafts other than its own tissue. Investigations of the inheritance of graft compatibility have now determined that multiple genes must be involved because compatibility is transmitted in an additive manner. With this new data, the seed orchard manager working with the tree breeder should be able to select highly compatible rootstocks for seed orchards. —PNW(933).

660. When ponderosa pine and Douglas-fir flowers were pollinated with their own pollen, the resulting seedlings were often smaller and had more cotyledons. In addition, seedlings resulting from controlled crosses were invariably larger than wind-pollinated seedlings. The superior growth of controlled crosses appears to be due to the more favorable cone and seed environment in the pollination bag. These growth differences could contribute to major errors in interpreting results of genetic tests, and tree breeders should be aware of them. —PNW(943).

661. Hybridizing different species of pines can result in trees with new and useful combinations of growth characteristics. The California Christmas Tree Growers, in cooperation with the Forest Service, produced and tested an artificially-produced hybrid between lodgepole pine and shore pine. After 5 years of field testing, results were mixed—some growers found the hybrids very useful, others found them worthless. Continued testing of new hybrids and selected species is needed to produce improved types of Christmas trees. —PSW(937).

662. A single 3000-year-old bristlecone pine that produces only white pollen was found in the White Mountains of California. The only other known example of a conifer producing white pollen is *Pinus resinosa*. By using pollen color as a genetic marker, studies with this unusual individual can contribute to our understanding of important developmental processes in trees. —PSW(899).

663. At what age is selection meaningful? New information from northern Idaho shows that selection for ponderosa and western white pine growth is not very reliable until the progeny are 15 to 20 years old. However, limited culling for poorest provenances or families could begin at about 10 years of age. Results indicate that, in the Inland Empire forests, tree breeders and forest managers must exercise caution in early selections. —INT(946).

664. Additional information concerning the patterns of genetic variation in western white pine is needed in order to accelerate the tree improvement program of this species. Identification of inheritance of single-gene traits is an approach to recognizing more complex traits. In an Idaho study, the presence or absence of a purple coloration of one cone was identified as a single gene. The next step is to correlate this gene and other known single genes with various characteristics of economic importance. —INT(945).

665. Efficient systems are needed to select trees or families for several desired traits simultaneously. A new system is proposed that employs: (l) Multiple counting and selection; (2) selection for the best trees on the basis of single traits, and (3) inter-trait correlations based only on families that are selected. When data were collected on flushing date, diameter, height, straight height, and number of leaders competing for dominance in two black walnut seed orchards in southern Illinois, the applicability of the new system could be demonstrated as a useful guide for selecting improved seed. —NC(927).

666. Grafting of one tree species onto another may stimulate early seed production. In a southern Illinois study, greenhouse grafting was at least partially successful for all combinations of three walnut species, and eight species and hybrids used as top or scion material. All grafting methods and graft wrapping materials tested were reasonably satisfactory; the techniques may be useful in establishing seed orchards. —NC(938).

667. The major cause of empty seed in Virginia pine appears to be embryonic lethal alleles when insect damage is eliminated. A study in the Virginia Piedmont showed that embryonic lethals in Virginia pine greatly reduce filled seed percentage following self-pollination. Seed orchard trees should be evaluated for the presence of lethal alleles, so that action can be taken to correct this problem. —SE(929).

668. Substantial losses of Virginia pine seed occur during maturation. Recent studies in Virginia have shown that, starting with a potential of 85 seed, only 23 percent filled seed were produced. Suggested causes of ovule and seed losses are insufficient pollen, insects, and embryonic lethal alleles. Most seed loss was apparently due to insects. Screen wire cages could be used to protect high value, control pollinated cones. —SE(928).

669. Choctawhatchee sand pine rootstocks are preferable for sand pine seed orchards, but grafting onto these rootstocks has been difficult. For a high proportion of grafts to succeed, both scion and the rootstock plants should have broken dormancy when the grafts are made. Scions should be gathered when terminal buds just begin to elongate and rootstock seedlings should have from 2 to 4 inches of new terminal growth. These techniques have resulted in 60 to 75 percent success as contrasted to 25 to 35 percent success when dormant scions and rootstocks were used. This information will greatly simplify the establishment of sand pine seed orchards. —SE(930).

670. Means are needed to improve pollination in seed orchards and increase yields of cones and filled seeds. Studies with slash pine in Florida have indicated that mass artificial application of pollen may help solve this problem, and that cross-pollen may have an advantage over self-pollen because of timing and embryonic competition. The first pollen applied always accounted for most of the resulting seedlings, but self-fertilized embryos were at a disadvantage when competing with cross-fertilized embryos. These results will be useful in formulating guidelines for mass artificial pollinations by orchard managers. —SE(935).

671. In order to test the value of individual tree phenotypic selections, some pine breeding programs are using a four or five male tester procedure. Recent data from 6-year-old single cross progenies of slash pine in Georgia show that, because of the relatively large proportion of genetic variance resulting from general combining ability effects, parental breeding values can be more cheaply estimated from progeny tests of open-pollinated or polycross seeds. —SE(939).

672. Tree breeding strategies necessarily require the breeder to choose among breeding and selection programs which vary in the amount of immediate genetic gain and the amount of gain which can be accumulated in future breeding generations. The two elements can be shown as functions of the effective parental population size. A new concept of a population rental is introduced, and an optimizing function is proposed. With this concept, planning for national or other long-term breeding programs can be based on a rational function which balances present genetic gain and future genetic opportunity costs according to an interest rate. —SE(941).

673. To maximize genetic gains per unit of time, tree breeders must utilize the results of progeny tests as soon as relative performance can be reliably predicted. Periodic measurements of stem growth and oleoresin yield in a slash pine progeny test in Florida showed weak correlations between measurements taken at 3 and 25 years. Correlations increased rapidly for subsequent measurements at 8, 14, and 18 years, however. The results indicated that the greatest genetic gain per year would be obtained by selecting at 10 years and by permitting a generation interval of about 14 years. —SE(944).

674. Tree improvement workers frequently use vegetative propagation techniques to increase material with desirable traits. With a new propagation method developed in Mississippi involving both environmental and chemical treatments, 83-100 percent of cuttings from pines up to 13 years old rooted in 6 to 12 weeks. A combination of auxins, sucrose, a fungicide, and a growth retardant induced the best rooting. If similar results are obtained in greenhouses, such treatments will find wide application in many phases of tree improvement research and practice. —SO(936).

675. Maintenance of germ plasm and narrowing of the genetic base are serious problems in highly-bred agricultural crops. Are there similar problems with forest trees? Based on a status review of forest tree breeding and efforts to preserve natural populations in place, the risk of significant loss of forest tree germ plasm seems small in the United States. Problems do exist in other countries, and forest geneticists must remain very conscious of risks to continued genetic diversity from tree breeding efforts. —WO-TMR(926).

Improving Uses and Protection of Wood

Utilization potential and processing of wood

676. It needs to be determined whether aerial row seeding is ready for commercial operations. Results of tests showed that aerial row seeding rates were too low, ranging from 542 to 3042 seeds/acre. Row spacing was erratic, but precision sowing from altitudes of 50 feet or less seems attainable. Areas of needed improvement were identified. An aerial row seeder is approaching practical usage although there are needed changes. —SO(1131,1147).

677. Removing a streak of bark and applying acid paste to stimulate gum flow from the living pine tree is the phase of gum harvesting requiring the highest level of skill and the greatest physical effort. A hydraulically-powered implement which can remove the bark streak and apply the acid paste automatically has been designed and a prototype fabricated and laboratory tested. If upcoming field tests are successful, the implement has the potential to reduce the skill level of the labor required and to increase the number of streaks removed per unit of time. —SO(1152).

678. Drying southern pine at high temperatures is becoming a standard practice, but some inefficiencies exist because basic principles are not well understood. Success in high temperature drying of thick veneers, lumber, timbers, and poles depends on moisture content variation, restraint during drying, air velocity, board thickness, temperature, and wet bulb depression. Understanding these factors will result in less loss during drying. —SO(1143,1200,1201).

679. Warp in kiln-dired southern pine causes very substantial degrade and loss of lumber value. A continuous kiln that provided complete mechanical restraint against warp brought pieces to 8.3 moisture content in 24 hours without casehardening and only half the warp found in conventional drying methods. These findings will stimulate commercial kiln manufacturers to improve their design. —SO(1202).

680. In conventional kiln drying with smooth sticks separating lumber courses, failure to restrain shrinkage stresses can result in warped lumber. Sharply toothed aluminum kiln sticks restrained the lumber during drying resulting in a straighter, more uniform product. This research suggests new practices can improve the quality of kiln-dried lumber. —SO(1204).

681. Closer utilization of trees and logging residues alters both net dollar returns and non-dollar costs and benefits. In a study of alternative levels of wood resource utilization in mature lodgepole pine, both dollar and non-dollar effects were evaluated. Net dollar returns were greater in conventional logging (removal of green sawlogs to a 6-inch top, with slash piled and burned) than in near-complete harvesting (sawlog removal followed by field chipping of remaining wood material on the site). However, substantial non-dollar benefits were gained by near-complete harvesting, especially in esthetics, fuel reduction, and site preparation. Continuing studies of harvesting influences upon soils, hydrology, nutrients, and regeneration will further define costs and benefits, and will provide managers with guidelines for harvesting practice decisions. —INT(1124).

682. Energy derived from wood residues seemed best suited for inplant steam and power production by the wood industry. It is possible that the production of high-value products or public absorption of the extra cost of utilization can make the other noted residue management alternatives more feasible. —PNW(1186).

683. The increased need for world pulp production has focused attention on forest residues as a source of fiber. Changes in timber sales procedures, such as negotiated lump-sum sales, service contracts, and compound contracts, are proposed and considered essential to facilitate more complete utilization. This study reports eight advantages to more complete timber utilization on the Pacific Coast. —PNW(1185).

684. Better techniques are currently available to determine the total amount of wood contained in sawtimber size trees. If industry is to improve its utilization practices, it must have improved methods of estimating the wood contained in the main stem as well as other parts of the tree. Timber buyers and sellers can use regression equations to estimate the amount of wood and bark in the main stem, as well as the small, medium, and large branches of lobolly pine trees. This will enable both buyers and sellers to appraise prices for all wood being sold. —SE(1244).

685. Through the use of computer simulation, a log can be "sawn" many different ways. Computer simulation provides statistically reliable comparisons of yields among various sawing methods. This technology allows sawmills to increase yields from short low-grade hardwood logs and small diameter bolts. —NE(1231).

686. In years ahead, it is anticipated that kraft pulp mills in the South will have difficulty harvesting sufficient wood to satisfy their requirements. A machine that harvests and bunches complete trees with taproots intact has been developed. Pulpwood yields per acre are increased by 20 percent and site preparation costs for reforestation are reduced. —SO(1132,1142,1144,1145).

687. The economic removal of hardwoods growing on land better suited for southern pines has been a problem for decades. The development of a shaping-lathe headrig shows how end-chucked hardwood or softwood bolts can be machined into cants for pallets, boards or posts of round or polygonal shape. Wood removed is in the form of flakes or pulp chips.

Cutting energy relates to wood specific gravity and flake thickness. This new equipment represents a major contribution to more efficient wood processing. —SO(1199,1203,-1205,1206).

688. Because of increasing demands for timber and changing utilization technology, chippable residues are now marketable products. There is a need for prediction equations and weight yield tables for estimating chippable residue, bark residue, lumber, and sawdust from various species. A series of reports for various species and products has been prepared. These data will permit timber owners and sawmill operators to estimate yields for standing timber. —SE(1158,1168,1169,1170,1226,1227,1245).

689. A 750-foot long skyline cable system was capable of clearcut logging 3.5 acres, removing tree length logs up to 24 inches d.b.h. in steep mountainous terrain, and, at the same time, reducing surface disturbance from road-building and skidding. The system shows promise for harvesting in the central Appalachians both for clearcutting and selective harvesting. —NE(1155).

690. Nonproductive time, or "down time", is a major cause of reduced profits in hardwood sawmills. Operations at 21 sawmills were observed. The average down time represents 11 percent of total operating time. The biggest part of down time was for repairs, but saw sharpening, log deck jam-ups, log trouble, and talk also reduced productivity. This information may be used by mill managers interested in pinpointing and reducing down time at their sawmills. —NE(1229,1230).

691. A better understanding of wood permeability is essential for the wood drying and treating industries. Air-drying and rewetting increased the saturation moisture content and the permeability of yellow-poplar by eliminating the air bubbles entrapped in the green wood. Hardwoods can be treated more effectively by air-drying the wood first to remove air bubbles. —NC(1163).

692. There is a need to examine why prefreezing improves black walnut drying. Prefreezing was found to increase radial permeability in both heartwood and sapwood of black walnut. Improved permeability probably caused the improvement in black walnut drying; thus, prefreezing might improve permeability—which in turn improves drying in other woods. —NC(1164,1173,1176).

693. The role that extractives play in the hygroscopicity and dimensional stability of wood needs to be investigated. The removal of extractives from black walnut heartwood caused greater shrinkage and a lower fiber saturation point than from the unextracted wood. Certain wood extractives might be added to wood to improve the dimensional stability and drying behavior of wood. —NC(1172).

694. The anatomical structure of northern red oak greatly affects the strength of lumber and the yield of pulp from the species. Wood from trees with a high proportion of fibers, and consequently a low porportion of vessels, is high in both strength and pulp yield. This study shows that average increases of 11 percent in fiber proportions occur when going from site index 25 to 85. Commensurate decreases are shown in the proportion of vessels, rays, and axial parenchyma. Positive relationships between fiber proportions and various mechanical properties are also shown. Of interest to silviculturists and forest managers is the constancy by which the proportion of fibers increases with site index and growth rate. —FPL(1220).

695. Continued consumer demands, particularly for construction lumber and plywood, coupled with a reduced commercial forest land base, make it imperative that consideration be given to more intensive forest management and wood utilization. Efforts to extend the timber supply include better utilization of forest residues. Opportunities to effectively utilize forest residues and research programs focused on this potential resource are reviewed. —FPL(1248).

696. Correct processing decisions in the manufacture of hardwood or softwood lumber require the machine operator to weigh hundreds or hundreds of thousands of alternatives. Since the time is limited and the requirements exceed human capabilities, the decisions are usually less than optimum. Our research is systematically solving this problem by the development of decisionmaking programs and systems for the lumber related industries. Examples include the hardwood lumber cutup program, the hardwood grading program, the Best Opening Face program, and the ultrasonic defectoscope system. Adoption of these systems by industry (now in progress) will greatly relieve the mental workload of machine operators and increase the efficiency of conversion by 10 to 20 percent. —FPL(1188).

697. Presently, lumber cutting decisions are based on what a sawyer sees and his capability to relate this information with product requirements. Inaccuracies and insufficient time result in reduced conversion efficiency. Research has developed an ultrasonic system to sense and locate defects in the work piece, and a computer to make processing decisions, and set and control the saw. Development of a production model and adoption by the industry will improve yields 8 to 12 percent. —FPL(1160).

698. Solutions to the geometrical problem of maximizing lumber yield from logs have eluded the industry for centuries. Precise mathematical modeling of the sawing process promises to solve this question. Such a mathematical model has been developed and in combination with maximization routines, is known as the Best Opening Face (BOF) computer program. Application of this technology as a sawing decision and machine control system is already underway in the industry and promises to increase yield from small logs by at least 10 percent. —FPL(1188,1189,1216,1217).

699. A study with press-lam, a structural product of thick, veneer parallel-laminated wood, has shown that a broad range of creosote retention in press-lam can easily be achieved by variation in treatment schedule, and that preservative penetration is independent of total uptake as compared to solid wood. The improved preservative treatability of press-lam expands the utility of this wood product. —FPL(1246).

700. Constructing particleboards of three layers with poorer material in cores and quality flakes on the surfaces can lead to best use of particle furnish. The dependency of panel stiffness on amounts and type of face and core material is illustrated both analytically and experimentally. The results advance the technology of how processing affects the physical properties of panels to be used in construction. —FPL(1182).

701. Forest residues constitute a vast quantity of largely unused wood raw material. Strong, stable, and durable structural particleboards can be produced from forest residues of Douglas-fir and associated species. Adequate properties can be maintained as long as only small amounts (less than 25 percent in total) of bark, badly decayed wood, or branchwood are included in the raw material mix. —FPL(1214).

702. From one-third to one-half of the face veneer produced from hardwoods grown in the United States buckles during drying and must be redried and flattened in a hot press before use. The experiment showed that buckle could be reduced to one-third that of controls by making the original drying in a hot press equipped with fourdrinier screen as cauls. Best

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results with 0.030-inch-thick black walnut were obtained by using a temperature of 230°F. a pressure of 50 pounds per square inch, and a drying time long enough to bring the veneer to about 6 percent moisture content. If the technique is adopted commercially, it should permit the use of lower grade hardwood logs for decorative face veneer. —FPL(1219).

703. The use of high density hardwoods for exterior construction plywood has not been possible because adhesive bonds did not meet the standards. The combining of high and low density hardwoods into one panel makes it possible to use an economical bond and meet the requirements of the standard, PS 1-66. This will permit the substitution of under-utilized eastern hardwoods for use in construction plywood and relieve some of the pressure on the softwood timber supply. —FPL(1198).

704. Research to evaluate supplementary treatments to utility poles in a high decay hazard environment was undertaken. Groundline wood preservative formulations were applied to weathered southern pine pole stubs initially treated with creosote. After 5 years of ground contact, the creosoted control stubs were severely attacked by decay fungi. The groundline treatments were highly effective in preventing decay. —FPL(1165,1184).

705. Performance of finishes on wood exposed outdoors can be vastly improved by treatment of wood surfaces with various inorganic compounds. Simple brush applications of aqueous solutions of the chemicals to wood surfaces can: 1) retard degradation of the surfaces by ultraviolet radiation; 2) enhance effective use of polymer coatings transparent to ultraviolet light; 3) reduce the swelling of wood by water; 4) impart a degree of fungal resistance to the surface and surface coatings; 5) serve to fix the extractives in redwood and red cedar; and 6) lengthen the life of oil-base and latex stains and coatings. Use of the treatment will improve wood as a substrate for finishing. —FPL(1159).

706. Shear blades have generally not been widely accepted as a tool for felling sawtimber due to excessive splitting damage in the butt log adjacent to the sheared face. Thin blades cause less splitting damage; however, they have limited structural stability. Methods to analyze the elastic stability of thin rectangular plates subjected to in-plane compressive loading with varying boundary conditons have been studied. These thin plate solutions can be used to approximate thin shear blade configurations. What is otherwise a very complicated problem has been reduced to a very simple checkout and design procedure which a design engineer can follow to estimate the stability of thin shear blades and to select methods of increasing elastic stability. —NC(1122).

707. Effective treatment of wood depends on the movement of treating liquid through the wood structure. A mathematical model was developed for evaluating moisture uptake, swelling, and moisture distribution during longitudinal penetration of water in once-dried yellow-poplar, black walnut, and red oak. Models of this type can help to predict effectiveness of various wood treatments. —NC(1233,1235).

708. Low-grade yellow-poplar is seldom processed to make high-quality dimension parts. Volume tables are given for low-grade yellow-poplar trees in a 30-year plantation for yield of clear-one-side, flat dimension parts. This information will aid the wood procurer to determine yields from low-grade wood. —NC(1175).

709. There is a need to build recreation structures from low-grade wood. Picnic tables, benches, shelters, cabins, and rustic signs for recreation areas, suitable for heavy use, can be made from No. 2 and No. 3 Common grades of lumber. The heavy hardwood resists vandalism and wear, and, when properly manufactured and maintained, will give many years of service in recreation structures. —NC(1174).

710. Conventional raw materials for pulp production are in short supply in the Four Corners region of Colorado, Utah, New Mexico and Arizona, limiting prospects for needed economic expansion. Evaluation of an inwoods debarking-chipping system showed that, with improved operating efficiency, cost of inwoods-produced chips could be nearly comparable to that of chips produced at a pulp mill from ponderosa pine and other coniferous roundwood. Substantial benefits were realized in woods cleanup. Quality of chips was excellent. Results have been used by pulp industry in planning expansion. —RM(1151).

711. One-fourth of Montana is forested. The forest's wildlife, recreational opportunities, forage, water, minerals, and timber are important to the economy and environmental quality of the State. Although some problems exist, progress has been made in reducing the conflicts among these uses and in reducing threats to air and water quality. About 11 percent of the State's personal income is directly or indirectly dependent on wood products, and expansion is planned in lumber, plywood, particleboard, and paper production. USDA Forest Service lands provide about half the annual wood harvest, so land use and management programs on National Forest lands have a major effect on supplies. Potential impacts of changes in National Forest harvest levels are estimated. This integrated overview should be of substantial value in long-term planning for the management and use of all forest resources in the State. —INT(1153).

712. Efficient transportation of forest products that is environmentally acceptable requires theoretical analysis of slope stability. The Rankine assumptions were used as a basis for developing equations for calculating active and passive earth pressures within a slope extending to infinity. The analysis considers cohesive and noncohesive soils, the angle of internal friction of the soil, seepage forces caused by a groundwater table parallel to the ground surface, and the plane on which the stresses are found. This research has particular relevance to problems of steep mountainous lands where engineers are studying slope stability and erosion problems. —INT(1137,-1138).

713. Hawaii has a number of useful woods that are not widely used at present. The physical and mechanical properties and appearance of 16 of these woods are described. Such information will help increase the use of these woods. —PSW(1240).

714. Detailed information is needed for quantification of lumber and veneer recovery factors for important commercial western species. A series of reports present these data for old and second growth Douglas-fir, Engelmann spruce, as well as red and white fir. These data are useful to timber managers and forest product manufacturing companies. —PNW(1178,1179,1192,1250,1251).

715. The evaluation of timber access road alternatives is difficult because comparison is related to such values as grade, length, curvature, and volume of excavation. A technique for rapid evaluation of alternatives is presented and should be useful to any engineering office having access to a high speed desk top calculator system with digitizer and plotter facilities. —PNW(1126,1127).

716. Today's rapid advancements in logging technology have created problems in maintaining current logging cost information. New approaches have been developed to reduce the time lag in determining logging costs of evolving timber harvesting systems. —PNW(1150).

717. Forest residues, both living and dead, are now being removed from cutting areas to improve aesthetic appeal and reduce fire and insect hazard. Evidence presented in a new compendium for the Pacific Northwest with contributions from 35 Forest Service authors indicates that a light amount of residue protects new seedlings against environmental extremes and that complete residue removal or destruction will serve as guidelines for land managers in the field of residue management and indicate areas in need of further research. —PNW(633).

Wood chemistry and fiber products

718. Kraft chemical pulping yields near 50 percent are a deterrent to accomplishing an extremely high degree of utilization of southern pines. Laboratory techniques provided visual evidence on how fibers could be unwound into more flexible ribbon-like structures. This study will provide information for design of a laboratory machine that will refine pulp for stronger paper at higher yield. —SO(1276).

719. Hardwoods on southern pine sites are being destroyed rather than utilized because of inadequate information on fiber dimensions. Data are presented for stem and branch fiber lengths for 22 hardwood species found on southern pine sites. This publication will aid manufacturers of fiber products in blending species to obtain desired properties. —SO(1275).

720. The corrosion of metal fasteners in wood often causes premature degradation of the wood and a reduced service life of the structure. This report describes the causes and prevention of wood failure due to metal corrosion. An understanding of the causes of wood degradation due to metal corrosion products will lead to better design and longer lasting structures. —FPL(1254).

721. Wood residues could be used as a source of animal feed if suitable ways can be found to break down the wood crystalline structure. Enzymes in ruminants' digestive systems can accomodate some wood untreated, but it was found that delignification of wood by normal wood pulping methods produces material with high rumen digestibility. Steers readily consumed a feeding ration composed of 50-75 percent pulp mill fines. Using wood as a roughage replacement would permit fuller utilization of residues and provide a new feed supply. —FPL(1255).

722. Outside storage of pulpwood chips gives rise to deterioration of the chips from the action of microorganisms and heat. Large amounts of byproducts, such as tall oil and turpentine, and some wood substance are lost. Two promising chemical treatments were evaluated in outside chip piles. One treatment suppressed initial heating and significantly reduced losses of tall oil, turpentine, and wood substance after 2 months storage. Chemical control of chip deterioration will not only conserve wood fiber, but pulp byproduct chemicals as well. —FPL(1289).

723. When green wood chips are stored in large outside chip piles, heating and degradation occurs results in losses of wood fiber. At 65.5°C, in the absence of microorganisms, green southern pine chips are degraded after only 3 months. Subsequent kraft pulping results in reduced pulp yields and pulp strength. Pretreatment of the wood with alkali will prevent loss in pulp yield. Untreated wood chips stored in large outside piles must be treated or protected to prevent or minimize heating and degradation. —FPL(1260).

724. Presently used wood preservatives are effective due to their toxic nature. A clean, permanent, nontoxic preservative making use of the chemical reactivity of wood with alkylene oxides under mildly alkaline conditons has been developed. Southern yellow pine showed good rot resistance to brown-rot fungi and very good dimensional stabilization when treated to 20-25 percent weight gain. Wood chemically modified in this way, shows promise for above ground application where reduction in water swelling and rot resistance are important. —FPL(1285).

725. To date, there has been no satisfactory method for measuring fiber bonding in paper. A highly useful fiber bonding index derived from web shrinkage energy and sheet density was developed which is free from the limitations of other methods and also offers new insight into the ultimate potential properties of cellulose-based fiber networks. —FPL(1256).

726. There is a shortage of detailed information on fiber recycling studies that simulate papermaking techniques. Conversion of wood into marketable paper products is dependent upon both the initial, or morphological, characteristics of the pulp fiber and on response of this fiber to processing variables. Without question, processing variables, such as beating, will affect sheet strength. However, under conditions of this investigation, sheet strength was influenced most by the original properties of the pulp fiber. —FPL(1268).

727. Conventional manufacturing processes for paper can result in variation of density across the thickness direction. This results in strength and stiffness differences of fiber products due to variations in fiber bonding. This study provides broad scale quantitative assessment of the influence of bonding intensity profiles which can be used as a guide for improving paper and board properties. —FPL(1291).

728. The utility of most fiber products depends on their inherent stiffness. Efficiency in design demands an adequate understanding of the factors which govern paper stiffness. Recent research suggests that there are relatively few factors and quantifies their importance. Factors examined include fiber orientation, density, restraint during drying, thickness, moisture content, and temperature. This information should be of general use to those trying to increase or obtain better control of paper stiffness. —FPL(1288).

729. In the manufacture of corrugated paper on a corrugating machine, fracturing of the corrugations limits how fast the paper can be run. Papermaking factors that affect the runnability of the medium on a corrugator and the strength of the product were established. A mathematical model was developed for predicting runnability from specific paper properties. This information is of immediate benefit to corrugating medium manufacturers in overcoming their present process problems and in providing the consumer with a better container. —FPL(1270).

730. The large volume of fiber in household trash has contributed greatly to the problem of solid waste disposal. This study showed that wood fiber from the paper fraction of household trash can be used in the manufacture of corrugating medium. Starch addition or mixing the waste fiber with pulp presently used in corrugating medium gives the necessary crush resistance. Thus one alternative to the disposal of household trash is by processing into corrugating medium. This dry recovery approach for wastepaper also provides a potential source of fiber to the rapidly growing container industry. —FPL(1273).

731. Wood fiber from urban residues like wastepapers, used pallets, dismantled railroad cars, and diseased elm trees has potential use in wood-base panel products such as medium-density board materials for furniture corestock. Dry-formed, medium density hardboards were made from various combinations of these residues. Most of the properties of the boards

were as good as those required for medium-density, mat-formed particleboard, but they were not as good as three commercial dry-formed, medium-density hardboards. This information will be useful for potential producers and consumers of these materials and to municipalities considering the use of waste for making panel products. —FPL(1274).

732. Pulping with oxygen reduces air pollution and produces 20 percent more pulp than in the kraft process. There are numerous technical problems such as the influence of transition metals, recovery of chemicals after pulping, and influence of wood species on the process. These problems are being attacked with success, and results will have a significant bearing in the development of a single stage oxygen pulping process. —FPL(1271,1272,1278,1279).

733. Softwoods were easily delignified with concentrated potassium hydroxide and sodium hydroxide under mild conditions. Although the cellulose was completely mercerized, the pulps were sufficiently strong but bulky and porous, and handsheet could not be densified to the level typical of kraft pulps. Unmercerized pulps prepared with 5N methanolic potassium hydroxide showed similar compositions and properties except they were more passive to beating. The comparison provided convincing evidence that hemicellulose distribution and cell wall microstructure—and not the mercerization--were critical factors in determining the pulp properties. —FPL(1259).

734. Disposal of fibrous hydrocolloid waste from pulp and papermills constitutes a major problem. *Thermomonospora fusca* is a bacteria that grows well on a variety of low-lignin pulps and papermill fines. Fermentation of such material at 55oC. with this bacterium effects a considerable reduction in their volume and produces a readily harvestable high value protein which can be used for animal or poultry feed. Upon prolonged fermentation, cell autolysis sets in that results in near complete digestion of carbohydrates and further reduction in sludge volume, thus functioning as an efficient disposal scheme. —FPL(1262).

735. Although there have been many publications concerning pine wood extractives, comprehensive studies of these extractives have been hampered by the inavailability of adequate analytical techniques. An analytical scheme has been devised that integrates several newly developed chromotographic procedures to give a detailed and quantitative picture of those pine constituents that are tall oil precursors. Our scheme has been used to obtain benchmark data on the extractives of loblolly pine wood, and on the changes that occur during pulping and storage of the chips. The analytical data permit quantitative evaluation of tall oil naval stores recovery as it relates to processing economics and product quality. —FPL(1295,1296).

736. Paper thickness determined according to conventional or standard methods is not suitable for the calculation of density or stress-strain properties of paper. Surface roughness of paper causes difficulty in the measurement of paper thickness. Inaccurate thickness measurement can result in density values as much as 80 percent off. A new definition and new equipment for measuring thickness that overcomes problems with conventional thickness measuring apparatus is proposed. This work has value to all scientists involved in paper research and is gaining worldwide acceptance. —FPL(1287).

737. If corrugated fiberboard is to be used efficiently in shipping containers to protect contents against thermal exposure or in building applications, a reliable method of calculating thermal properties is necessary. A mathematical model has been developed—based on summation of resistance of individual components--which provides estimates of steady-state thermal resistance within plus or minus 6 percent. Designers or others involved in protecting contents can utilize corrugated fiberboard more efficiently since total heat transfer resistance can be accurately estimated for any thickness. —FPL(1284).

Wood engineering

738. Architects and builders know little about changes in moisture that occur behind brick siding or conventional wood siding in exterior insulated wood-frame walls. A study of moisture gradients in these two wall types was made during winter in a mild climate in Athens, Ga. The results show that the wood frames behind brick siding will remain dry during winter even if the interior vapor barrier is broken or omitted because of the air space normally provided between the brick and wall sheathing. The wood-sided wall must contain an interior vapor barrier to stay dry. Properly constructed wood-frame wall systems, using either brick or wood siding, can be expected to remain structurally sound without costly deterioration from dimensional instability, paint peeling, and wood decay, caused by high moisture levels. —SE(1305).

739. Wood has been in a poor competitive position in the guardrail support market owing to a lack of knowledge of how its impact strength characteristics compared with steel posts. Using the Southwest Research Institute's pendulum facility and high-speed movies, it was found that smaller sizes of lower grades of wood are equal or superior to standard steel posts. These results, in combination with earlier work on machine driving (NE-81 and NE-212), are the basis for an industry-Forest Service effort to change State guardrail post specifications. Success in this effort will provide an expanded market for the over-abundant lower grades of wood. —NE(1308).

740. The correlation between the strength and stiffness of lumber is the subject of worldwide investigation in grading research. This paper describes a laboratory instrument developed to detect stiffness variations within pieces of lumber over distances of less than 2 feet. The middle-ordinate method provides a laboratory means of objectively assessing the strength-reducing potential of localized defects in lumber. —FPL(1313).

741. Static bending tests were conducted on small clear specimens from untreated piles salvaged from the Milwaukee River. Strength and stiffness of red pine pile material was substantially lower than published values for the species; white pine and tamarack results showed little or no apparent effects due to the river exposure. Lumber cut from the red pine piles would not be recommended for structural applications using allowable design values for the species. The results of this study challenge traditional positions which have suggested no degradation takes place under immersion. —FPL(1300).

742. There is a need to reevaluate wood properties so that existing reference data will adequately represent the current resource. The mechanical properties and specific gravity of a random sample of black, red, and white spruce and balsam fir were measured on specimens green and at 12 percent moisture content. Average values important in design with lumber and plywood were higher in 23 cases, lower in 6, and unchanged in 11. This data will be submitted by industry for ASTM approval and application to design use in lumber, plywood, and poles. —FPL(1299).

743. Imprecise design procedures for stressed skin panels have resulted in inefficient utilization of materials. Experi-

mental work showed that "shear flow" and "shear lag" mathematical analysis provide an efficient design basis. Use of the analysis leads to better panels with less material. —FPL(1314).

744. Prestressed wood beams have often been advocated in construction, but little is known regarding inherent changes that might result over extended time periods. To evaluate the change in prestressing force due to time-strain characteristics of the wood, matched pairs of prestressed and nonprestressed control beams were loaded for 8 years. The time deflection performance of the matched pairs was consistently similar, and there was no significant loss in the prestressing force. These data indicate that prestressed beams should give adequate performance in structures. —FPL(1301).

745. The wood-frame house is believed to be overbuilt, resulting in inefficient use and waste of the wood resource. Tests conducted during progressive construction stages of a 16- by 24-foot house to determine influence of each component on overall performance showed structural failures were in connections rather than in wood members. Failure loads were far in excess of design loads. This information will guide future research to establish efficient design criteria for wood homes. —FPL(1330).

746. Condensation problems in houses are a major cause of excessive maintenance and heating costs. Research has shown that proper location of vapor barriers and insulation coupled with improved construction techniques will minimize condensation problems. Adoption of the research findings can improve house durability and reduce heating energy requirements. —FPL(1298).

747. The quantity of lumber suitable for engineered glulam timbers could be substantially increased if presently prohibited coarse-grain materials were permitted. Compared to beams with existing permissible combinations, those containing coarse-grain material would likely have only slightly reduced bending strength and stiffness but substantially reduced shear strength. Data have already been used by the glulam industry to establish a specification. Research findings provide a tool to permit more complete and efficient use of the timber resource. —FPL(1324).

748. Glulam timbers, using multiple species in a single assembly, can stretch high grade timber supplies if desired strength and stiffness can be maintained. A theoretical concept permitting combinations of different species within the same beam was developed and evaluated. Research shows that glulam beams made with low strength lodgepole pine inner laminations and high strength Douglas-fir outer laminations will have desired strength properties. Design criteria presented can be used to determine the extent to which lower strength species can be used and the effect on beam properties. The research provides means for more complete and efficient use of the timber resource. —FPL(1325).

749. In addition to softwood plywood, the homeowner has several choices of panel products for new construction or remodeling jobs. Many of these products are made partly or entirely of wood-based material—hardwood plywood, insulation board, hardboard, laminated paperboard, particleboard, and gypsum board. Each product will serve well if used as intended. Information presented will help the homeowner select the materials that best fit his need and pocketbook. —FPL(1331).

750. Noise is a form of pollution which especially effects residential privacy. Single-row-of-wood stud walls are an important alternative for airborne sound insulation for party walls in multifamily dwellings since they use less material, than, for example, a double-row-of-stud construction. Four different types of design were evaluated under laboratory and field conditions. Two of the designs showed good potential for party wall applications. Results are important to building code groups, builders, and building inspectors because the advantages and limitations of this type of structure are shown. —FPL(1312).

751. Code officials recognize certain inadequacies in defining "noncombustible" materials. A potentially improved method based on "rate of heat release" of a material has been proposed. Information on rate of heat release and methods of reducing it are provided for typical wood-base building materials. Results are important to regulatory officials, researchers, material producers, and others interested in improved and accurate methods of determining combustibility limits and in the proper acceptance of the fire safety of wood products compared to other building materials. —FPL(1303,1304).

752. Because there is extensive loss of life and property damage due to fire, it is necessary to fully understand the fire performance characteristics of wood used in dwellings. This report summarizes information on ignition, resistance to fire penetration, flame spread, smoke development, heat release, fire retardants and fire retardant treated wood. This information is needed by architects, coding authorities, and builders for efficient, safe dwelling construction. —FPL(1310,1311).

753. A knowledge of comparative fire endurance characteristics of structural sandwich panels is necessary if acceptance criteria are to be established for use in single family and other housing construction. Tests conducted on wall panels, loaded to calculated design load and incorporating a variety of face and core materials, provide valuable information on fire endurance characteristics of both sandwich panels and wood-frame wall panels. Performance data on panels incorporating techniques to extend fire resistance are also presented. Feasibility of utilizing sandwich construction is important to code and other regulatory authorities, architects, and builders. —FPL(1306).

Biological degradation

754. Wood decay involves an extremely complex process that is very important to nutrient recycling in forests as well as to wood preservation and durability throughout the world. Brown-rot fungi, which primarily degrade carbohydrates—such as cellulose--and are reported to produce hydrogen peroxide much more rapidly than white-rot fungi, appear to depolymerize cellulose through a hydrogen peroxide-ferrous iron system. White-rot fungi appear to modify lignin in a process that is largely oxidative. The procedure by which one white-rot fungus, *Polyporus dichrous*, oxygenates specific compounds during lignin biodegradation has been delineated. Biochemists and fungus physiologists will be able to base further research on this information. —SE(469,532,533).

755. The discoloration of asphalt roofing shingles is a problem for homeowners in warm, moist regions of the United States. A blue-green alga was consistently identified as the organism primarily responsible for the discoloration of shingle granules. A variety of fungi, bacteria, and other algae were also isolated from discolored granules, but these were of minor importance although the fungi severely affected the strength of shingles. Recognition of the organisms that cause roof discoloration will permit researchers to develop control procedures. —SO(528).

756. In recent years, an unknown fungus has seriously degraded large softwood chip piles in the United States, Canada, and Sweden. Mycological studies have shown this to

be a new *Phanerochaete* with a *Chrysosporium* imperfect state. Now that is has been identified, researchers can concentrate efforts on developing a technique for controlling the damage caused by this fungus. —FPL(531).

757. Even though termites cause hundreds of millions of dollars worth of damage to wood and wood products each year, their digestive physiology remains poorly understood and controversial. The eastern subterranean termite, the most widely distributed and damaging termite species in North America, proved an efficient degrader of cellulose and hemicellulose and a poor degrader of lignin. Despite this species' reported ability to fix atmospheric nitrogen, the total nitrogen in the termite-wood test system decreased during the 4-week test period. A better understanding of termite nutrition and digestive physiology should increase the possibility of achieving practical termite control through a highly selective description or blocking of termite feeding. —FPL(431).

Prevention and control of wood-destroying organisms

758. Fungi and insects cause considerable damage to wood throughout the country. This damage is especially important when it involves high-value or critical items such as posts, poles, or supporting components of buildings. Techniques have been developed for recognizing and preventing or minimizing this damage. Pest control operators, architects, builders, and others will be able to contribute toward reducing wood loss by implementing these techniques. —SO(529,530).

759. Although wood of most species is severely damaged by termites, certain woods seem relatively immune from termite attack. Components extracted from Port-Orford cedar, eastern redcedar, western redcedar, baldcypress, and redwood contained substances detrimental to termite attack and survival. Once these termite detrimental compounds are isolated and identified, either they or closely related compounds may possibly be used to protect susceptible wood from termite damage. —SO(429).

760. Wood from Central America is a potentially valuable addition to our native wood supply, yet we know very little about many of the woods' resistance to subterranean termites. Of 97 wood species, 14 permitted no survival by either of the two test organisms—one native and one introduced termite species. Thirty-one additional wood species permitted no survival of the native species and only low survival of the introduced species. These groups of woods were considered resistant. Identifying the compounds responsible for the resistance of Central American woods to subterranean termites may lead to the development of selective termiticides or nontoxic repellents or feeding deterrents. —SO(428).

761. Although the wood-destroying beetle, *Xyletinus peltatus* is probably the most damaging beetle of seasoned wood in the southeastern United States, the factors influencing its choice of wood species for egg-laying are unknown. Contrary to their typical habit of damaging softwood timbers in buildings, they preferred a hardwood—yellow-poplar--for egg-laying. The basis for this selection is unknown. Additionally, the beetles preferred rough surfaces for egg-laying. This beetle is obviously capable of damaging many woods used in homes, and its abundance in softwoods probably reflects building practices more than beetle preferences. —SO(433).

762. Preliminary experiments with toxic baits to control subterranean termites have given favorable results in southern Canada; however, we need to know how effective this technique would be in the South where termites are much more abundant. Baits were placed on a grid at 5 foot intervals and each bait used a very small amount of a toxic chemical. Termite attacks were effectively suppressed for 3 years with a single bait treatment. The toxic bait treatment appears sufficiently promising to expand research by testing its efficacy against a variety of termite species in different climates under a variety of operational conditions. —SO(430).

763. Improper log storage prior to sawing at mills results in serious losses of wood quality and quantity. These losses can be avoided with properly constructed and maintained storage facilities that minimize conditions favoring insects, fungi, and stain damage to logs before they are sawn in the mill. A checklist provides standards to be met by modern log yards to eliminate damage during the storage period. Proper storage will increase quantity and quality of lumber produced from hardwood logs. —SO(432).

Marketing Under-used Species and Residues

764. Recent enactment of anti-pollution regulations promoted the development of new processes and markets for utilizing bark residues. Bark products have been developed for use in agriculture, industry, and construction. Markets for mulches and soil conditioners have been established in the horticultural trades and garden stores. The 1972 market for horticultural bark products was estimated at $30-40 million. Research and development efforts in processing, handling, and application of bark have provided timber processors with alternative use opportunities in most sections of the country. —NE(1062,1063,1064,1065,1066,1070,1071).

765. Low density wood species have long been considered inferior for production of durable pallets. Research has determined that species such as aspen can be used effectively provided the lumber is properly used and the pallets are adequately designed. Aspen pallets can be at least 1 1/3 times as stiff and 1 1/5 times as rigid as oak pallets of the same basic design. Use of low density species can greatly increase supplies of raw material suitable for pallets. —NE(1067,1068,1069).

Supply, Demand, and Price Analysis

766. How much should be invested in forestry today and in the near future to provide the timber that will be needed at the end of this century and beyond? This study attempts to answer the question for the State of Georgia. It provides a systematic means of assessing the long-run economic outlook for investments in Georgia forestry. —SE(1084).

767. North American production and consumption of wood-based panels increased rapidly over the past decade, and the industry continues in a state of rapid change. New products and processes are continually being developed. Large, new production plants are being built. This suggests strong interproduct competition for raw materials and for markets in the years ahead. This view of current and prospective trends in the wood-based panel industry is of interest to all those concerned with production and consumption of wood raw materials and finished products. —WO(1086).

768. Information on the amount of wood products consumed in construction of nonresidential buildings is needed for accurate assessment of current and prospective demand for timber. The volume of lumber and panel products used in different types and structural classes of buildings was measured. Wood use factors were developed. The volumes of different wood products used, by building type and building component, are presented for use of processors, marketers, and others interested in the size and nature of this important market and

its effect on the current and prospective demand for timber products. EWO(1087,1088).

769. There is widespread interest in, and need for information on the demand and price situation for forest products. Current timber industry statistics on production, prices, trade and related items have been brought together and analyzed for ready reference of producers, marketers, consumers, consultants and others interested in up-to-date information about the forest products situation and trends. The time series data on production, imports, exports and consumption form the basis for assessment of current and prospective demand for timber. —WO(1074,1075,1076,1085).

770. The demand for housing is a major determinant of the prospective demand for lumber, plywood, and other forest products. Declining population growth and major shifts in the age structure of the population in coming decades will profoundly affect both the number and type of dwelling units required in the second half of the 1970's and beyond. This information is vitally important to all timber growers and processors. —NC(1081,1082).

771. Despite the high lumber and plywood prices associated with housing booms, wood products have not been a major cause of increased housing costs. Analysis of housing input prices, home ownership costs, and house prices in the postwar period show that rising land costs, taxes, wage rates, and interest rates contribute to rising housing costs. The outlook suggests that factors other than building material supplies will control future housing production. —SO(1077).

Improved Marketing Systems

772. Extreme variation in sizes of loads hauled on Appalachian logging trucks prevents optimization of hauling costs. Measurement of 125 loads from seven cutting sites showed differences of 10,000 pounds and 1,000 board feet per load even for the same truck, driver, and cutting site. Four out of five trucks were loaded below legal weight limits. Hauling costs can be reduced at least $5.00 per MBF by increasing average load size through use of higher stakes, presorting and proper placement of logs on the load, and double tiering short logs to use more of the available cargo space. —NE(1115).

773. Conventional grade-sawing of small, low-grade hardwood logs is generally unprofitable for mills without resaw equipment. Live-sawing resulted in reduction of break-even log diameter from 12 to about 9 inches. Use of the live-sawing method will permit hardwood sawmills to saw more low-grade logs and help extend the hardwood timber resource. —NE(1099).

774. A national pallet exchange program could reduce materials handling and distribution costs by many millions of dollars. Research indicates that performance of warehouse and exchange pallets depends on quality of pallet shook, deckboard-stringer fasteners and fastening system, construction design specifications, and conditions of use. Prudent application of such research and development results can reduce initial pallet cost, increase pallet life, and decrease overall pallet use costs. —NE(1091,1114,1116,1117).

775. High labor turnover in wood products industries results in wasted manpower, needless production losses, and higher costs to the industry and its consumers. Quit rates in wood industries were found to increase during expansions in economic activity and to fall during recessions. Changes in quit rates over time can be explained by variations in unemployment rate, composition of the labor force, and earnings of wood industry workers relative to other workers in the economy. This study helps to explain present levels of wood industry labor mobility and identifies factors that are likely to determine future changes. —NE(1118).

776. Producers of pure maple syrup have little knowledge of consumers' preferences and purchase habits. Users of maple syrup in syrup-producing regions differ from consumers in other parts of the country. A survey analyzed differences in user attitudes, preferences, and purchase and use patterns. Results are being used to guide the United States Maple Institute in developing a national promotion program for maple syrup. Other research has shown how to increase efficiency and lower costs in production and distribution of maple syrup so as to improve its competitive position with lower-priced maple blends. —NE(1089,1097,1108,1109).

777. Purchasing pulpwood by weight is becoming established practice in the Lake States, but accurate weight-volume conversion factors for Minnesota pulpwood have been lacking. Seasonal weight-volume relationships were determined for aspen and black spruce and are now being used by buyers and sellers to establish more equitable pulpwood weights for sale transactions. —NC(1102).

778. Raw materials for pulp production are in short supply in the Southwest, limiting prospects for expansion. Evaluation of inwoods pulp chip production showed that cost of woods-produced chips could be comparable to chips produced at mill from ponderosa pine and other coniferous roundwood. Substantial benefits accrued from woods cleanup. Chip quality was excellent. Results have been used by the pulp industry in planning expansion. —RM(1107).

779. Timber managers and operators often can't decide what utilization alternatives produce highest values from a given timber base. A unique multiproduct inventory system coupled with a computer program (MULTI), calculates timber volume in a number of product classes. Any set of product specifications may be stated, and value priorities may be set to maximize volume of highest value products. Results will be used by local industry and forest managers to determine best product mix. —RM(1119).

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219-692 O - 76 - 8

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219-692 O - 76 - 9

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1974. Methods of nailing and adhesive consistency affect the strength of nailed-glued construction joints. Forest Products Journal 24(12): p. 17-22.—(SE)

AUTHOR INDEX

Numbers Refer to Publication List

A

Adams, T.C. 541
Aho, P.E. 435, 445, 446
Aizawa, I. 391
Alban, D.H. 655, 656, 657
Aldon, E.F. 45, 144
Aldrich, R.C. 1009
Alexander, R.R. 100, 759, 760, 878, 881
Alston, R.M. 1025
Amburgey, T.L. 528, 529, 530
Amidon, E.L. 879
Amman, A.G. 321
Amman, G.D. 321, 322
Amman, S.L. 321
Anderegg, R.J. 1253
Andersen, W.H. 577
Anderson, A.E. 202
Anderson, H.E. 578, 579
Anderson, H.W. 46
Anderson, L.O. 1298
Anderson, W.C. 956, 1030, 1031, 1054
Anderson, W.H. 580
Andrews, T.L. 396
Anonymous 1089, 1090, 1091
Applefield, M. 1092
Arola, R.A. 1120, 1121, 1122
Asano, T. 1123
Ashley, M. 496
Aubertin, G.M. 136, 146, 147, 149
Auchmoody, L.R. 658, 894
Austin, J.W. 1093

B

Bailey, R.L. 860, 861
Baker, A.J. 1254, 1255
Baker, J.B. 659
Baker, M.B. Jr. 51, 55, 1046
Bakshi, B.K. 684
Balmer, W.E. 797, 841
Bande, M.B. 715
Barber, J.C. 926
Barger, J.H. 397
Barham, R.O. 447
Barham, S.H. 1173, 1176
Barker, P.A. 269, 284, 285, 286, 289
Barnard, J.E. 957, 958, 1010, 1012
Barnett, J.P. 479, 798, 799, 800
Barney, R.J. 581, 595, 600
Barras, S.J. 323, 346
Barrett, J.W. 751, 761
Bartels, J.M. 324
Bartos, D.L. 155, 244
Bassett, P.M. 959, 960
Bate, L.C. 325
Bauer, E.O. 829
Baughman, R.G. 601
Baumgartner, D.C. 1112
Baumgartner, D.M. 762
Beagle, L.D. 852
Beal, R.H. 428, 430, 530
Beale, D.M. 203
Bearce, B.C. 183, 184, 1065
Beardsley, W.G. 287
Beaton, J.A. 436
Beck, D.E. 682, 781, 853, 863
Beckwith, R.C. 390
Bedard, W.D. 398
Bega, R.V. 448
Beland, J.W. 444
Belanger, R.P. 801, 857
Bellamy, T.R. 987, 988, 989
Beltz, R.C. 1130
Bendtsen, B.A. 1299, 1300
Bennett, F.A. 864, 1158
Bennett, W.H. 407
Benson, R.E. 1051, 1124, 1153
Bergen, J.D. 617, 618, 619
Berglund, E.R. 581
Bernardi, G.C. 542
Bertelson, D.F. 990, 991, 992, 993, 994
Bevins, M.I. 288
Bey, C.F. 903, 927, 940
Bhattacharya, N.C. 709, 1020, 1021
Biesbrock, J.A. 502
Biller, C.J. 141, 780, 1141, 1155
Billingsley, F.C. 1277
Birch, M.C. 326
Bishop, D.M. 121
Black, J.M. 1159
Blackburn, W.H. 156
Blackmon, B.G. 660
Blair, R.L. 890
Blair, R.M. 233
Blanchard, R. 173
Blum, M.S. 371
Blyth, J.E. 995, 996, 997, 998, 999
Bodkin, R.E. 1211
Boelter, A.H. 996
Boelter, D.H. 47, 48, 49, 50
Bohannan, B. 1301, 1302
Bohlool, B.B. 502
Boldt, C.E. 763
Bollen, W.B. 13, 23, 142, 449, 519
Bolsinger, C.L. 1019
Bones, J.T. 997, 1000, 1001, 1002
Bonner, F.T. 685, 802, 803
Boone, R.S. 1247
Borden, A.W. 620
Bormann, F.H. 148
Borovicka, R.L. 14
Boster, R.S. 1032, 1055
Bourne, C.E. 503
Bousfield, W.E. 376
Bowden, D.C. 202
Bowers, T.M. 957, 958
Bowman, K.O. 621, 629
Boyce, S.G. 854
Boyer, W.D. 747, 748, 749
Bracke, J.W. 327
Brackebusch, A.P. 559
Bradley, E.L. 424
Brady, H.A. 782, 783
Bramlett, D.L. 919, 928, 929
Brand, J.M. 327
Brander, R.B. 303
Brendemuehl, R.H. 930
Brenden, J.J. 1303, 1304
Brender, E.V. 563
Brewer, J.W. 450
Brickell, J.E. 1011
Brink, G.E. 101
Brisbin, R.L. 1177
Brodie, J.E. 1094
Broido, A. 602, 603, 611
Brown, C.L. 817, 835
Brown, G.R. 192
Brown, G.W. 154
Brown, H.E. 51
Brown, J.K. 543, 582, 604, 1125
Brown, R.E. 577, 580
Brown, R.W. 1, 2, 3, 4, 5, 30, 52
Brown, T.C. 1032, 1044
Brown, T.L. 288
Bruce, D. 865, 866, 867, 877
Buchman, R.G. 277
Buckhouse, J.C. 289
Buckman, R.E. 1045
Buech, R.R. 632
Bulgrin, E.H. 1160, 1161
Burandt, C.L. Jr. 237, 757
Burck, M.W. 1162
Burdge, R.J. 276
Burdsall, H.H. Jr. 451, 452, 531
Burgan, R.E. 53
Burke, D. 1126, 1127, 1128
Burns, R.M. 797, 804
Burton, J.D. 668, 764, 765
Bussey, A.H. 583
Byram, G.M. 605
Byrd, V.L. 1256, 1257

C

Cable, D.R. 157, 252, 253
Cahill, D.B. 422
Cameron, S.I. 714
Campbell, R.K. 805, 891, 892, 931
Campbell, R.W. 328, 329, 330
Campbell, T.E. 722, 723, 806, 819, 1147
Cannon, W.N. Jr. 383
Capp, J.P. 38
Caraway, C. 1174
Carkin, R.E. 766
Carl, C.M. Jr. 851
Carmean, W.H. 661
Carson, W.W. 1129
Carter, A. 232
Carter, F.L. 428, 429
Caulfield, D.F. 1258
Caylor, J. 317
Cecich, R.A. 686, 687, 708
Chacko, B. 715
Chakravorty, A.K. 458
Chang, H. 532
Chappell, T.W. 819, 1130, 1131, 1147
Chen, P.Y.S. 1163, 1164
Chibbar, R.N. 693
Chien, M. 640
Choate, G.A. 959, 960
Christopher, J.F. 1003, 1004
Chudnoff, M. 1165, 1166, 1167, 1180
Clark, A. III 1168, 1169, 1170, 1244
Clark, E.W. 331, 365
Clark, R.N. 290, 299
Clarke, E.H. 570
Clary, W.P. 54, 55, 1046
Clausen, K.E. 807
Clayton, J.L. 151
Clema, J.K. 622
Clements, R.W. 950, 951, 952, 953
Close, G.E. 50
Cobb, M. 168
Cole, G.L. 288
Cole, W.E. 332, 333

Coleman, M.D. 159
Collyard, K.J. 450
Coltharp, G.B. 289
Conner, R.N. 204
Connors, W.J. 1259
Cook, D.I. 740, 743, 744
Cooley, J.H. 25, 808
Cooley, R. 775
Cooper, D.T. 905
Cooper, G.A. 855, 859, 1164, 1171, 1172, 1173, 1174, 1175, 1176, 1225
Cooper, R.W. 544
Copes, D.L. 932, 933
Cordell, H.K. 291
Cotrufo, C. 662
Coughran, S.J. 1132
Countryman, C.M. 545, 584
Coyne, J.F. 920
Cramer, O.P. 546, 547, 633
Crandall, C.R. 558
Crawford, D.L. 1262
Crawford, H.S. 204
Critchfield, W.B. 721, 899, 920, 1297
Croker, T.C. Jr. 750
Crouch, G.L. 727, 728
Cunningham, M.L. 1065
Cunningham, R. 24
Cunningham, W. 173
Cupal, J.J. 205, 219
Currier, J.B. 149
Curtis, R.O. 663, 664, 868, 869
Curtis, W.R. 27
Cutchins, M.A. 1131
Czabator, F.J. 444

D

Dahlgreen, A.K. 809, 832
Dahms, W.G. 751
Daniels, O.L. 585
Danielson, C.W. 996
Darley, E.G. 568
Darr, D.R. 1038, 1056
Daterman, G.E. 315, 377, 380, 402
Dauterman, W.C. 404
Daves, G.D. Jr. 380
Davidson, W.H. 28, 29
Davis, E.A. 90
Dawson, D.H. 501, 856, 921, 924
Dawson, G. 606
DeBano, L.F. 56, 57
DeBarr, G.L. 316, 334, 335, 373, 688
Debyle, N.V. 58
Deeming, J.E. 555, 586, 587
DeGraaf, R.M. 206, 207, 208, 213, 238
DeGroot, R.C. 1095
Deiss, D.H. 295
del Toro, G.A. 882, 883
Della-Bianca, L. 784, 853
DeMars, C.J. 317
DeMars, D.J. 866, 867, 868, 869
Denison, W.C. 142, 519
Dewey, J.E. 399
Dhaliwal, G. 710, 711
Dhir, N.K. 689, 690
Dick, R.E. 292
Dickerhoof, H.E. 1095
Dickerson, B.P. 59
Dickson, D.R. 1000, 1001
Diem, K.L. 243
Dietrichson, J. 805
Dietz, D.R. 209, 211, 229
Dillow, M.K. 691
Dinus, R.J. 922, 925
Divakaran, R. 715
Dochinger, L.S. 534, 535, 538, 540
Donley, D.E. 318, 319
Donnelly, D.M. 1107, 1151
Donoghue, L.R. 548, 549
Doolittle, M.L. 550
Dorman, K.W. 186, 893
Dorn, D.E. 894
Doty, R.D. 150
Douglass, J.E. 60, 61, 62, 63, 109, 129
Dress, P.E. 880
Driscoll, R.S. 158, 159, 160, 210
Driver, B.L. 300
Drooz, A.T. 364
Dubois, N.R. 406
Duchacek, H. 1097
Duff, J.E. 1305
Duffy, P.D. 6, 7
Dunmire, D.E. 1177
Dutrow, G.F. 1026, 1033
Dwinell, L.D. 453
Dykstra, D.P. 551
Dyrness, C.T. 634

E

Earles, J.M. 968, 969, 970, 986, 1024
Ebel, B.H. 334, 336
Echelberger, H.E. 293, 294, 295
Edgerton, P.J. 161, 163
Edgren, J.W. 810
Edminster, C.B. 873, 878
Edmonds, R.L. 351
Effland, M.J. 1281
Egging, L.T. 1133, 1136
Eickner, H.W. 1306
Elliott, E.R. 573
Elliott, S.T. 199
Ellis, W.D. 728
Elsner, G.H. 296
Engalichev, N. 1002
Erdmann, G.G. 724
Erickson, J.R. 1121
Esenther, G.R. 430, 431
Eslyn, W.E. 531
Essex, B.L. 961, 962, 984
Estep, E.M. 552, 553, 1186
Ethington, R.L. 1307, 1309
Evans, H.J. 446
Evans, K.E. 211
Evans, L.S. 536, 539
Evett, M. 602
Ewing, B. 317

F

Fahey, D.J. 1270
Fahey, T.D. 1178, 1179
Farmer, E.E. 64
Farmer, E.F. 30
Farr, W.A. 636
Fasick, C.A. 1096
Fatzinger, C.W. 337
Fay, H. 483
Fay, S. 65
Fechner, G.H. 716
Fedde, V.H. 338, 339
Federer, C.A. 66, 67, 68, 91
Feist, W.C. 1260, 1289
Ferguson, E.R. 730, 789, 790
Ferguson, R.B. 162
Ferguson, R.H. 963, 964
Ferrell, G.T. 340
Ffolliott, P.F. 98
Fight, R.D. 1034, 1045, 1056
Filer, T.H. Jr. 443
Filip, S.M. 678
Firmage, D.H. 599
Fish, E.B. 254
Flake, H.W. Jr. 386, 400
Fober, H. 665
Folkman, W.S. 314, 554
Fosberg, M.A. 622, 623
Fowler, D.P. 908
Fowler, R.F. 401
Fowler, W.B. 69, 70, 71, 72, 73, 74
Francis, R.E. 160
Frank, R.M. 785
Franklin, E.C. 890, 895, 934, 935, 1261
Franklin, J.F. 634, 649
Frayer, W.E. 1012
Frazer, R.E. 1277
Freas, A.D. 1180
Freese, F. 1181
French, D.W. 465
Frye, R.H. 350
Fryer, J.H. 902
Fujioka, F.M. 53
Fuller, M.R. 212
Funk, D.T. 726, 811, 822, 850, 938
Fuquay, D.M. 606
Furniss, M.M. 402
Furnival, G.M. 341

G

Gabriel, W.J. 947, 948, 949
Gaddis, K.D. 1211
Gale, R. 1177
Galford, J.R. 319, 342
Galoch, E. 706, 707
Gansel, C.R. 944
Gardner, R.B. 1134
Garrett, L.D. 1097
Gary, H.L. 75, 76, 77, 78
Gatchell, C.J. 1308
Gedney, D.R. 1093
Gee, G.W. 67, 68
Geeseman, D. 349
Gehring, G.A. Jr. 588
Geimer, R.L. 1182, 1214
Geist, J.M. 163
George, C.W. 597
Gerdemann, J.W. 454
Gerhards, C.C. 1309
Getty, R.E. 307
Gibson, D.F. 1133, 1134, 1135, 1136
Gibson, H.G. 79
Gilbertson, R.L. 451, 452, 470, 471
Gill, J.D. 183, 184, 213, 214, 240, 779, 1047
Gill, T.G. 1072
Gillette, N.L. 415, 416
Gist, C.S. 80
Giunta, B.C. 255
Gjovik, L.R. 1165, 1183, 1184
Godfrey, E.B. 1059
Godwin, P.A. 409
Goetz, E.J. 218
Gonsior, M.J. 1137
Gove, J.P. 692
Gove, W.G. 1002
Graber, R.E. 642, 645, 812
Graham, D.A. 491
Granskog, J.E. 1031
Grantham, J.B. 1185, 1186
Grasham, J.L. 459
Gratkowski, H. 635, 786, 787
Gravelle, P.J. 414
Graves., T.M. 417
Gray, J.R. 1098
Green, A.W. 965
Green, J. 1286
Greene, L.E. 403, 411
Gregor, S. 455
Grelen, H.E. 164, 165, 245
Grigal, D.F. 273
Grimble, D. 406
Grimm, T.R. 1122
Grismer, M.A. 474
Grosenbaugh, L.R. 870
Gupta, S. 712
Gurumurti, K. 693, 694
Guttenberg, S. 1035
Gutzmer, D.I. 1285

H

Habermann, H. 1219, 1302
Hackskaylo, E. 719
Hahn, J.T. 966, 967, 978, 998
Hair, D. 1085
Haissig, B.E. 456, 499, 500, 695, 696, 697
Hajny, G.J. 1260
Hall, D.J. 343, 344
Hall, D.O. 196, 788

Hall, J.D. 17
Hall, R.B. 698
Hallock, H. 1187, 1188, 1189, 1216, 1217
Halls, L.K. 178, 215, 228
Halsey, D.G. 589
Halverson, H.G. 81
Hamilton, D.A. Jr. 871
Hamlen, R.A. 427
Hamptom, D. 151
Hanks, D.L. 166
Hanks, L.F. 1190
Hann, D.W. 1013, 1014
Hanover, J.W. 896
Hansen, B.G. 1073
Hansen, E.A. 82, 83, 84, 85, 152
Hare, R.C. 699, 922, 936
Harkin, J.M. 457, 1262, 1263, 1264, 1265, 1266
Harlow, R.F. 216
Harniss, R.O. 174, 175, 246, 250
Harrington, J.J. 583
Harrington, T.A. 955
Harris, A.R. 85, 152
Harris, A.S. 636, 767
Harshbarger, T.J. 86, 87
Hart, T.P. 1028
Hartsog, W.S. 1137, 1138
Harvey, A.E. 458, 459, 494, 495
Harvey, G.M. 460, 484
Hastings, F.L. 404
Haw, M. 495
Hawes, R.B. 527
Hawksworth, F.G. 461, 497, 526
Hay, C.J. 319, 345, 381
Hazard, J.W. 1015, 1016
Healy, W.M. 217, 218
Heaton, G.C. 394
Hedlund, A. 968, 969, 970, 986
Heebink, B.G. 1191
Heede, B.H. 8
Hegg, K.M. 971
Heidmann, L.J. 813, 814, 827
Heinselman, M.L. 274
Heisler, G.M. 741
Helfman, R.S. 555
Heller, R.C. 1017
Helmers, A.E. 106, 121, 124
Helrich, K. 397
Helvey, J.D. 72, 73, 74, 88
Helvig, T.N. 598
Hendee, J.C. 275, 276, 290, 297, 298, 299
Henley, J.W. 553, 1192
Henry, W.R. 300
Herman, F.R. 868, 869
Herrington, L.P. 742
Herrington, R.B. 287
Hibbert, A.R. 89, 90, 94, 1044
Hill, R.W. 31
Hiller, P.K. 219
Hinds, T.E. 378
Hirata, G.H. 53
Hitt, R.G. 186
Hodges, C.C. 602
Hodges, C.S. 15
Hodges, J.D. 323, 346
Holmes, C.A. 1282, 1310, 1311, 1326
Holmgren, R.C. 203, 247
Holt, E. 1074, 1075, 1076
Holt, W.R. 383
Homeyer, J.W. 64
Hook, D.D. 752
Hookana, E. Jr. 150
Horn, R.A. 1267, 1268
Hornbeck, J.W. 91, 92, 93
Host, J. 1139
Host, J.R. 1140
Hotta, Y. 700
Hough, W.A. 556
Houston, D.R. 462, 463, 464, 513
Howard, E.T. 1193, 1194
Howard, J.O. 1005, 1007
Howes, C.D. 916
Hoyle, M.C. 692
Hse, C. 1195, 1196, 1197
Huang, C.T. 404
Hudler, G. 465
Hug, W.L. 17
Hughes, J.M. 889
Hughes, R.H. 248
Huneycutt, M.B. 140
Huyler, N.K. 1099

I

Ignoffo, C. 391
Ingebo, P.A. 94
Irland, L.C. 1048, 1077, 1078
Irwin, R.L. 589
Isebrands, J.G. 703
Israelsen, C.E. 31

J

Jacobs, R.D. 768
Jain, M.K. 1021
James, G.A. 291
Jameson, D.A. 244
Jaynes, R.A. 897
Jeffers, R.M. 731
Jenkinson, J.L. 898
Jennings, D.T. 347, 348, 400
Jensen, C.E. 236
Jensen, K.F. 537, 538
Jeppson, R.W. 31
Johansen, R.W. 557
Johnson, B.R. 1241
Johnson, D.L. 809
Johnson, E.P. 729
Johnson, K.L. 95
Johnson, L.C. 899, 937
Johnson, L.R. 1141
Johnson, N.E. 361
Johnson, P.S. 753
Johnson, V.J. 549, 565
Johnston, R.S. 96
Johnston, W.F. 754
Jokerst, R.W. 1198
Jones, A.S. 15
Jones, J.H. 938
Jones, J.R. 637, 769, 815, 816
Jones, R. 732
Jones, R.E. 1312
Jorgensen, C.D. 220
Jorgensen, J.E. 1129
Jorgenson, J.R. 666

K

Kaeiser, M. 938
Kallio, E. 1100, 1102
Kaplan, R. 301
Kasemir, H.W. 606
Kass, A.J. 1313
Kato, K.G. 580
Kaur, N.P. 1020
Keiser, G.M. 733
Kellison, R.C. 900
KenKnight, G.E. 503
Kennedy, H.E. Jr. 638
Kennedy, P.C. 395
Kennell, R.A. 778, 1043
Kessler, G.D. 837
Kessler, K.J. Jr. 437, 466
Khan, A.G. 667, 679
Kickert, R.N. 599
Kingsley, N.P. 972
Kirk, T.K. 431, 467, 532, 533
Klages, M.G. 756
Kline, L.N. 402, 405
Klock, G.O. 105
Klungness, J.H. 1269
Knight, H.A. 439, 973, 974, 975, 976, 985, 1058
Knoerr, K.R. 133
Knopf, J.A.E. 387
Knutson, D.M. 468
Koch, P. 1132, 1142, 1143, 1144, 1145, 1199, 1200, 1201, 1202, 1203, 1204, 1205, 1206
Kochenderfer, J.N. 136, 141, 780, 1155
Kochhar, V.K. 709, 712, 713
Koenigs, J.W. 469
Koenigshof, G.A. 1079, 1101
Koeppen, R.C. 1180
Kok, C.T. 661
Kologiski, R. 639
Koning, J.W. Jr. 1270, 1280
Kormanik, P.P. 335, 688, 752, 817, 835, 837, 857, 923
Koss, W.D. 1059
Kourtz, P.H. 296
Kozlowski, T.T. 537
Kraus, J.F. 939
Krawczszyn, J. 701
Kriesel, K. 702
Krinard, R.M. 638
Krochmal, A. 639, 640
Krueger, W.C. 249
Krugman, S.L. 926
Ku, T.T. 668
Kuenzi, E.W. 1314
Kumar, P. 713
Kung, F.H. 927, 940
Kurtenacker, R.S. 1315

L

La Farge, T. 901
LaBau, V.J. 1018
Laidly, P.R. 811
Laing, F.M. 1097
Landt, E.F. 1207, 1208, 1209, 1210, 1211
Landucci, L.L. 1271, 1272
Lanier, G.N. 324
LaPage, W.F. 302
Larsen, M.J. 457, 467, 470, 471, 472, 1263
Larson, F.R. 97, 98, 137
Larson, P.R. 703
Larson, R.G. 304
Laundrie, J.F. 1273, 1274
Laurent, T.H. 1018
Lauterbach, P. 787
Lavdas, L. 624
Lawson, E.R. 730, 789, 790
Laycock, W.A. 249, 250
Leaf, A.L. 16
Leaf, C.F. 9, 99, 100, 101, 881
Leak, W.B. 641, 642, 643, 644, 645
Leaphart, C.D. 473, 474
Ledig, F.T. 902
Lee, R. 704
Lehmann, W.F. 1182, 1212, 1213, 1214, 1243, 1247
Lengel, J.E. 1302
Leonard, R.E. 16, 65
Letourneau, L. 1010
Lewey, H.J. 1215
Lewis, C.E. 251
Lewis, D.W. 1189, 1216, 1217
Lewis, F.B. 372, 406, 427
Lewis, W.C. 1329
Li, C.Y. 475
Liegel, L.H. 882, 883
Lightle, P.C. 476
Likens, G.E. 92, 93, 148
Lime, D.W. 277, 278
Limpert, F.A. 102
Limstrom, G.A. 811
Lindmark, R. 1100
Lindquist, J.L. 734, 872
Linlor, W.I. 103, 104
Lipkowitz, K.B. 349
Lister, C.K. 422
Little, E.L. Jr. 735, 736, 738, 739
Little, S. 646, 647, 737, 903
Litton, R.B. Jr. 270
Lloyd, F.T. 648, 682, 864
Lloyd, J.D. Jr. 1006
Lockyer, J.W. 413
Loftus, N.S. Jr. 818
Lohrey, R.E. 669, 791, 858
Loomis, R.M. 558, 590
Lopushinsky, W. 105, 116
Lora, M.E. 917

Lorence, G.A. 278
Lorenz, L.F. 467, 533
Lorio, P.L. Jr. 407
Lotan, J.E. 756
Lothner, D.C. 1080, 1102
Lotspeich, F.B. 106
Lott, C.E. Jr. 450
Louie, N.A. 577
Lucas, R.C. 279
Lucht, D.D. 350
Luedecke, A.D. 597, 598
Lundgren, A.L. 1049
Lutz, J.F. 1198, 1218, 1219
Lyon, R.L. 411, 415
Lyon, W.S. 325
Lysons, H.H. 1146

M

MacConnell, W.P. 167, 168, 169, 170, 171
MacLachlan, R. 305
MacLean, C.D. 1019
Madgwick, H.A.I. 705
Maeglin, R.R. 1220
Maksymiuk, B. 408
Mann, W.F. Jr. 670, 791, 819, 1147
Manwiller, F.G. 1275
Marcin, T.C. 1081, 1082
Marden, R.M. 1102
Margo, P.M. 477
Mark, W.R. 526
Markovetz, A.J. 327
Marquis, D.A. 725
Marsalis, R.L. 399
Martin, D.C. 1179
Martin, G.L. 1137, 1138
Martin, N.E. 514, 515
Martin, R.E. 86, 559
Martin, S.C. 252, 253, 254
Martinelli, M. Jr. 107
Marx, D.H. 447, 478, 479
Maser, C. 649
Mason, C.J. 351
Mason, R.R. 352
Massey, C.L. 353
Mattson, J.A. 1148, 1154
Mattson, W.J. 354
Mauldin, J.K. 433
Maxwell, J. 149
May, J.T. 626
Mayer, C.E. 963, 964
McAlister, R.H. 1316, 1317, 1318, 1319
McAlpine, R.G. 752
McArthur, E.D. 166, 172, 191, 255
McCambridge, W.F. 355, 356, 357, 423
McCartney, W. 498
McCauley, O.D. 770, 1036
McClure, J.P. 439, 974, 975, 1058
McClurkin, D.C. 7, 108, 140
McCluskey, D.C. 239
McConaughy, D. 903
McConnell, B.R. 161
McConnell, W. 173
McConnen, R.J. 1039, 1051, 1153
McCoy, E. 1262
McCracken, F.I. 480, 481
McCutchan, M. 625
McCutchan, M.H. 620
McCutcheon, W.J. 1320, 1330
McDonough, W.T. 4, 5, 52, 174, 175, 176, 177
McGee, C.E. 781, 820
McGilvray, J.M. 670, 798
McGinnes, E.A. Jr. 438, 1221, 1294
McGovern, J.N. 1241
McGregor, M.D. 392, 399
McGuire, D.H. 999
McKee, D.T. 292
McKee, W.H. Jr. 671
McKinney, R.K. Jr. 1014
McKnight, J.S. 1028
McLean, H.R. 574
McLemore, B.F. 821
McMahon, C.K. 573
McMillin, C.W. 1222, 1276, 1277, 1321
McNatt, J.D. 1274, 1322, 1323
McQuilkin, R.A. 672
McReynolds, R.D. 953
McSwain, M.R. 109
Mead, R.A. 160
Mech, L.D. 221, 231, 241, 303
Medin, D.E. 202
Meehan, W.R. 197, 198, 199, 200, 222
Mees, R.M. 591, 592
Meeuwig, R.O. 156
Megahan, W.F. 10, 11, 110, 151
Meier, M.F. 103
Mendel, J.J. 778, 1043
Merkel, E.P. 421
Merriam, L.C. Jr. 280, 281
Meskimen, G.F. 895
Messner, H.E. 209
Michie, J.D. 1308
Michniewicz, M. 702, 706, 707
Micklewright, J.T. 1086
Miksche, J.P. 689, 690, 698, 700, 708
Miles, R.S. 681, 943
Miller, D. 414
Miller, G.E. 376
Miller, P.R. 536, 539
Miller, R.A. 22, 201
Miller, R.E. 673, 674, 675, 683
Miller, W.E. 358
Millett, M.A. 1255
Mills, T.J. 1027, 1028, 1083
Miniutti, V.P. 1246
Minor, J.L. 1278, 1279
Minore, D. 766
Mitchell, R.G. 359, 360, 361, 362, 363
Mobley, H. 560
Mobley, H.E. 561, 562, 563
Moeller, G.H. 304, 305, 306, 307, 308, 309
Moessner, K.E. 98
Mohaupt, A.A. 1280
Moir, W.H. 634
Monsen, S.B. 162
Montgomery, A.A. 1084
Montrey, H.M. 1182
Moody, R.C. 1324, 1325
Moore, D.G. 17, 18
Moore, G.E. 364
Moore, W.E. 1258, 1281
Moore, W.H. 256
Morby, F.E. 832
Morris, R.C. 432
Morrison, D.A. 295, 304, 305, 308
Morselli, M. 1109
Moser, J.C. 365, 369, 370, 371, 379
Mosher, D.G. 366
Mounts, J. 410
Mraz, E.A. 1159
Mufich, J.G. 8
Muggli, J.M. 367
Mullavey, R.W. 558
Mundy, B.P. 349
Murphy, P.A. 976
Murray, F.W. 613
Mutch, R.W. 593
Myers, C.A. 423, 771, 873
Myers, G.C. 1282, 1326

N

Nagy, J. 229
Namkoong, G. 650, 941
Nanda, K.K. 693, 694, 709, 710, 711, 712, 713, 1020, 1021
Navon, D. 1037
Neary, D.G. 25
Neely, D. 822
Neely, R.D. 368
Neisess, J. 410
Nelson, E.A. 651
Nelson, E.E. 482, 483, 484
Nelson, L.E. 659
Nelson, M.A. 603
Nelson, N.D. 1223
Nelson, R.E. 111
Nelson, R.M. Jr. 605
Nestler, F.H.M. 1283
Nevel, R.L. Jr. 1103, 1104
Newman, R.P. 761
Nicholls, T.H. 212, 465, 485, 486, 509, 521, 524
Niedzwiedz, W. 169
Nienstaedt, H. 904, 942
Nixon, C.M. 726
Nixon, E.S. 237, 757
Nolley, J.W. 1094, 1105
Norris, L.A. 13, 18, 19, 20, 21, 22, 200
North, D.W. 594
Norum, R.A. 607, 614
Noyes, J.H. 223

O

O'Connell, P.F. 55, 1044, 1046, 1055
Oberg, R.R. 724
Obst, J.R. 457, 1263, 1264, 1265, 1266
Odell, T.M. 409
Oefinger, S.W. Jr. 178
Offensend, F.L. 594
Ohmann, L.F. 273
Oliver, D.J. 714
Oliver, W.W. 823
Olson, D.F. 648, 705
Orchard, R.D. 408, 410
Orr, H.K. 112, 113
Ostrom, A.J. 977, 978, 980
Oviatt, A.E. 1224
Owston, P.W. 824, 836

P

Pace, G.D. 609, 610
Packer, P.E. 30, 32, 33
Page, M. 403, 411, 416
Palmer, T.Y. 608, 609, 610
Panzer, H.R. 1219
Parker, J. 487, 488, 489
Patric, J.H. 12, 147, 240, 779
Patton, D.R. 179, 224, 225
Paul, H.G. 362
Paul, J.T. 626, 627
Payne, B.R. 226
Peacock, J.W. 418
Pearson, H.A. 257, 258, 259, 260, 261, 262, 263, 266, 983
Pedersen, R.J. 227
Peirsol, M.K. 1190
Pepper, W.D. 929
Perala, D.A. 564, 755, 792
Percival, R.M. 595
Perkins, C.J. 86
Peters, P.A. 1149, 1150
Peters, W.J. 954, 955
Peterson, G.L. 282, 283
Peterson, G.W. 490, 491, 492, 516, 522
Phares, R.E. 726, 850, 859, 1225
Phelps, R.B. 1072, 1085
Phillips, D.R. 1226, 1227, 1245
Phillips, R. 79
Phipps, H.M. 825
Piatt, J.R. 180
Pickford, S.G. 568
Pierce, R.S. 91
Pierovich, J.M. 1186
Pillai, S.K. 715
Plank, M.E. 1192
Plass, W.T. 34, 35, 36, 37, 38, 39, 43
Pleasonton, A. 1057

Plummer, A.P. 166, 181, 182, 190, 236, 255
Podwaite, J.D. 368
Pogge, F.L. 183, 184
Polley, C.W. 1290
Ponce, S.L. 153, 154
Pong, W.Y. 1228, 1251
Pottle, H.W. 493
Powers, H.R. Jr. 439, 453, 527, 1058
Powers, R.F. 676
Prey, A.J. 485, 486
Price, D.A. 249
Progulske, D.R. 223
Promnitz, L.C. 1016
Pywell, H.R. 170
Pywell, N.A. 171

Q

Quinney, D.N. 1061, 1086

R

Radwan, M.A. 727, 728, 826
Ragain, D.P. 302
Ramaker, T.J. 1284
Randall, R.M. 1038, 1060
Randall, W.K. 905
Rasmussen, L.A. 322
Rast, E.D. 1229, 1230
Ratliff, R.D. 185, 264
Reeves, H.C. 228
Regelin, W.L. 229
Rehfeldt, G.E. 906, 907
Reid, C.P.P. 716
Reid, W.H. 1087, 1088
Reppert, J.N. 264
Reukema, D.L. 663, 664, 674
Rexrode, C.O. 412, 413
Reynolds, H.W. 1231
Rice, R.M. 114
Rich, L.R. 115
Richards, T.A. 271
Richardson, B.Z. 30
Rietveld, W.J. 732, 827
Riffer, R. 611
Riley, F.M. Jr. 1096
Riley, R.G. 369, 370
Ringold, G.B. 414
Rink, G. 39
Roach, B.A. 772, 773
Robb, J. 494, 495
Roberds, J.H. 650
Roberts, C.F. 625
Roberts, D.R. 955
Robertson, D. 171
Robertson, J.L. 415, 416
Robinson, S.W. 371
Robinson, V.L. 1084, 1106
Roche, L. 908
Rogers, J.J. 51
Rogers, L.L. 230
Rollinson, W.D. 372
Ronco, F. 828
Roselle, R.E. 419
Rosen, H.N. 1232, 1233, 1234, 1235, 1236
Ross, T.L. 306
Rothacher, J. 116
Roussopoulos, P.J. 565, 604
Rowan, S.J. 373
Rowe, J.W. 1253
Rowell, R.M. 1285
Rozej, B. 706
Rudinsky, J.A. 405, 417
Rudolf, P.O. 186
Rudolph, T.D. 652, 829
Ruehle, J.L. 447
Russell, T.E. 830, 831
Ryan, B.C. 628
Ryan, P.W. 566
Ryan, R.B. 374, 375, 376
Ryker, R.A. 809, 832

S

Sackett, S.S. 567
Safford, L.O. 496, 677, 678
Sahibzada, M.A. 679
Salunkhe, D.K. 285, 286
Sampson, G.R. 1107, 1151
Sandberg, D.V. 568, 569
Sanders, C.J. 377
Sanders, D.W. 1152
Sanks, R.L. 1123
Santeford, H.S. 117
Sanyer, N. 1259, 1271, 1272, 1278, 1279
Sarles, R.L. 1062, 1063, 1064
Sartwell, C. 363
Sartwell, C. Jr. 417
Sartz, R.S. 118, 119
Sassaman, R.W. 1050
Satter, L.D. 1255
Saucier, J.R. 801
Savage, S.M. 120
Schaedle, M. 714
Schaffer, E.L. 1246, 1327
Scharpf, R.F. 440, 497, 498
Schier, G.A. 187
Schipper, A.L. Jr. 456, 499, 500, 501, 924
Schlesinger, R.C. 855, 1175
Schmid, J.M. 350, 378
Schmidt, E.L. 502
Schmidtling, R.C. 909, 910
Schmiege, D.C. 121
Schmitz, R.F. 405
Scholl, D.G. 90
Schopmeyer, C.S. 188, 833
Schreiber, L.R. 418
Schreiner, E.J. 911
Schreuder, H.T. 122, 123, 130
Schroeder, J.G. 1158, 1169, 1227, 1245
Schubert, G.H. 774
Schuldt, J.P. 1007
Schultz, R.P. 680, 834
Schuster, E.G. 1059
Schweitzer, D.L. 1034, 1039, 1051, 1060, 1153
Scott, E.G. 1065
Scott, R.W. 1286
Seal, U.S. 231
Sears, H.S. 200
Seehorn, M.E. 63
Segelquist, C.A. 233
Seidel, K.W. 653, 775
Seidler, R.J. 446
Seliskar, C.E. 503
Sendak, P.E. 1108, 1109
Sesco, J.A. 1110
Setterholm, V.C. 1287, 1288
Setzer, T.S. 965, 979
Severson, K.E. 232
Sexson, G.D. 419
Shafer, E.L. Jr. 271, 307, 308, 309
Sharon, E.M. 504, 505, 506
Sharpnack, D. 884
Shaw, M. 458, 494
Shenton, L.R. 621, 629
Shepherd, R.F. 377
Shepperd, W.D. 878
Sherwood, G.E. 1298
Shigo, A. 442
Shigo, A.L. 438, 441, 442, 493, 496, 506, 507, 508
Short, H.L. 233
Shoulders, E. 671, 764
Siccama, T.G. 148
Siegel, W.C. 1040, 1041, 1042, 1052, 1111
Silen, R.R. 663, 664
Silverstein, R.M. 369, 370
Simpson, W.T. 1237, 1238
Sims, P.L. 155
Sinclair, W.A. 443
Skau, C.M. 156
Skilling, D.D. 486, 509, 521, 523, 524, 525
Skolmen, R.G. 1239, 1240
Slabaugh, P.E. 190
Slaughter, C.W. 124
Smalley, G.W. 793, 860, 861
Smart, C.N. 594
Smiley, R.L. 379
Smith 117
Smith, C.K. 280, 281
Smith, H.D. 220, 234
Smith, J.A. 160
Smith, J.G. 161
Smith, J.L. 81, 102, 103, 104, 125
Smith, R.G. 380
Smith, R.S. Jr. 492, 510
Smythe, R.V. 420, 429
Sneeuwjagt, R.J. 612
Snow, G.A. 444
Solomon, D.S. 776
Solomon, J.D. 381
Solverson, L. 1112
Sommer, H.E. 835
Sommerfeld, R.A. 126, 127
Sommers, W.T. 630
Sorensen, F.C. 681, 943
Southwell, C.R. 428
Sowa, E.A. 29
Speers, C.F. 382, 421
Spencer, J.S. Jr. 962, 980
Spink, L.R. 1050
Spomer, L.A. 1066
Springer, E.L. 1260, 1289
Springfield, H.W. 180, 189, 235
Squillace, A.E. 893, 912, 913, 944, 1261
Srago, M. 440
Srihadiono, U.I. 1241
Stage, A.R. 885, 886, 887
Staley, D.H. 383
Standaert, J.P. 330
Stankey, G.H. 290, 299, 310
Stark, N. 614
Steele, R.W. 614
Stein, A.M. 613
Stein, J.D. 384, 385
Stein, W.I. 190, 777, 824, 836, 841
Steinbeck, K. 837
Steinhagen, H. 1113
Steinhoff, R.J. 945, 946
Steinmetz, P.E. 1290
Stermitz, J.E. 756
Stern, E.G. 1067, 1068, 1069, 1114, 1116, 1117
Sternitzke, H.S. 263, 266, 981, 982, 983
Stevens, P.M. 570
Stevens, R. 191, 236
Stevens, R.E. 386, 387, 422, 423, 455
Stewart, H.A. 1242, 1243
Stewart, R.E. 794, 795, 796
Stockmann, V.E. 1291
Stowers, K.L. 13
Strange, J.D. 1084
Stransky, J.J. 237, 757
Straub, R.J. 596
Strickler, G.S. 163
Strobel, J.J. 1116
Sturges, D.L. 128
Sturos, J.A. 1154
Sullivan, J.G. 613
Sundahl, W.E. 838
Superfesky, M.J. 1328, 1329
Sutherland, J.C. 25
Swank, W.T. 80, 122, 123, 129, 130
Swanson, D.H. 597, 598
Swanson, J.R. 571
Swanston, D.N. 131, 132
Swift, L.W. 133
Swindel, B.F. 874, 875, 1158
Switzer, G.L. 659
Sypolt, C.R. 704
Szczotka, Z. 717

T

Tabler, R.D. 134
Taras, M.A. 1168, 1169, 1170, 1227, 1244, 1245
Taylor, A.R. 599, 615
Telek, L. 916
Tester, J.R. 212
Thames, J.L. 254
Thilenius, J.F. 192

Thomas, H.A. 424
Thomas, J.W. 206, 207, 208, 213, 226, 227, 238, 239
Thompson, J.C. 1055
Thompson, J.R. 115, 135
Thor, E. 39
Timson, F.G. 1115
Tinus, R.W. 718, 839, 840, 841
Tluczek, L. 24
Tolsted, D.N. 118, 119
Toole, E.R. 480, 481
Torgersen, T.R. 388, 389, 390
Towlerton, A.L. 1123
Townsend, A.M. 540
Trappe, J.M. 434, 454, 511
Travis, M.R. 296
Trimble, G.R. Jr. 240, 654, 758, 770, 778, 779, 1036, 1043
Troendle, C.A. 136
Trousdell, K.B. 682
Trujillo, D.P. 816
Tryon, E.H. 654
Tschernitz, J.L. 1246
Tuomi, R.L. 1320, 1330
Turner, J.C. Jr. 556
Turner, J.M. 137, 1053
Twombly, A.D. 1050
Tyre, G.L. 291, 857, 1096

U

Urie, D.H. 24, 25, 26
Utz, K.A. 797

V

Vago, C. 391
Van Ballenberghe, V. 231, 241
Van Deusen, J.L. 763, 876, 914
Van Epps, G.A. 193, 194
Van Haverbeke, D.F. 740, 743, 744, 745
Van Hooser, D.D. 1022, 1023
Van Kekerix, L. 5
Van Lear, D. 640
VanEtten, C.H. 1236
Vasilevsky, A. 967, 984
Venator, C.R. 842, 915, 916
Vick, C.B. 1334
Viereck, L.A. 738, 739
Vincent, J.R. 1048
Vital, B.R. 1247
Vogel, W.G. 41, 42
Vozzo, J.A. 719, 843, 844, 845

W

Waddell, C.D. 525
Wade, D.D. 572, 573, 587
Wadsworth, F.H. 736
Wagar, J.A. 272, 287, 292, 312, 313, 314
Wagle, R.F. 616
Wahlgren, H.E. 1248
Wallin, W.B. 1069, 1116, 1117
Wallmo, O.C. 229
Walters, G.A. 846, 847
Walters, R.S. 746, 949
Ward, A.L. 205, 242, 243
Ward, D.E. 267, 572, 573
Ward, F.R. 574
Ward, J.C. 1249, 1252
Ware, K.D. 880, 888, 889
Wargo, P.M. 512, 513
Wartluft, J.L. 1070, 1071
Washburn, R.I. 392
Watrous, R.J. 109
Watson, E.S. 140
Watson, T.C. 210
Wawriw, R. 1165
Weatherwax, R.C. 1292, 1293
Webber, R.W. 600
Weeks, R.W. 205, 219, 243
Weiss, M.J. 476
Welch, B.L. 514, 515
Welch, G.D. 550
Welch, R.L. 985, 1008
Wells, G.R. 986, 1024
Wells, O.O. 917, 925
Wendel, G.W. 141, 780, 1155
Wengert, E.M. 1249
Werner, R.A. 425
Werren, F. 1331
West, N.E. 246
Wheeler, D.M.S. 516
Wheeler, M.M. 516
Whitaker, L.B. 260, 261
White, J.R. 43
White, W.B. 409
White, Z.W. 877
Whitesell, C.D. 848, 862
Wicker, E.F. 517, 518
Wicklow, M.C. 142, 519
Wiens, D. 455
Wilcox, W.W. 1228
Wilhite, A.T. Jr. 268
Wilhite, L.P. 680
Wilkins, L. 640
Wilkinson, R.C. 365, 918
Wilkinson, T.L. 1332, 1333
Williams, C.B. Jr. 426
Williams, D.T. 563, 575, 631
Williams, G.P. Jr. 44
Williams, K. 143
Williams, L.H. 420, 433, 530
Williams, R.D. 849, 850
Williams, S.E. 144
Williamson, R.L. 675
Wilson, L.F. 343, 344, 366, 393, 394, 395, 401
Wilson, R.W. Jr. 341
Wodzicki, T.J. 720
Wolf, C.H. 1118
Wollum, A.G. II 144
Wolters, G.L. 195, 268
Wood, D.L. 398
Woodard, P.M. 576
Woodbury, R.O. 736
Woodfin, R.O. Jr. 1250, 1251
Woodson, G.E. 1321
Worley, D.P. 214, 1029, 1047
Worth, H.E. 1107, 1151
Wright, K.H. 361
Wright, M.G. 1087, 1088
Wu, K.Y. 1294

Y

Yamamoto, T. 145
Yates, H.O. III 320, 336
Yawney, H.W. 729, 851
Yendol, W.G. 427
Yerkes, V.P. 1119, 1156
Young, D.C. 673, 683
Young, P.E. 170

Z

Zahn, J.J. 1314
Zajaczkowski, S. 720
Zak, B. 520
Zatorska, Z. 706
Zeikus, J.G. 1252
Zerillo, R.T. 368
Zinkel, D.F. 721, 1295, 1296, 1297
Zobel, B.J. 890, 900
Zoch, L.L. Jr. 1289
Zornig, H.F. 1334

TAXONOMIC INDEX

Numbers Refer to Publication List

A

Abies amabilis 634
Abies balsamea 442, 643, 644, 645, 647, 1299
Abies concolor 340, 352, 392, 440, 446, 450, 759, 769, 823, 1228, 1238, 1251
Abies grandis 105, 360, 435, 520, 653, 775
Abies lasiocarpa 378, 429, 759, 760, 878, 881
Abies lasiocarpa var. *arizonica* 759, 769
Abies magnifica 392, 823, 1251
Abies pindrow 684
Abies procera 868
Abies spp. 363, 440
Acacia koa 846, 847, 1240
Acarina 365, 379
Acaulospora spp. 454
Acer circinatum 727, 795, 796
Acer grandidentatum 269, 285, 286
Acer pennsylvanicum 644
Acer rubrum 364, 493, 496, 504, 507, 540, 564, 642, 677, 758, 782, 1207
Acer saccharum 67, 68, 441, 466, 477, 487, 489, 512, 513, 537, 564, 643, 644, 645, 677, 729, 851, 947, 948, 949, 1120, 1148
Acer spicatum 644
Acer spp. 411, 442, 464, 508, 817, 966, 1177
Acremonium spp. 452
Acromyrmex octospinosus 371
Adelges cooleyi 362
Agathis pumila 376
Agrilus acutipennis 318
Agropyron intermedium 3
Agropyron spp. 30
Allantonema spp. 353
Alnus rubra 142, 519, 727, 796, 868
Alnus rugosa 513
Alnus spp. 667, 679
Alsophila pometaria 364, 416
Andropogon scoparius 164, 165
Andropogon spp. 680
Angiospermae 438, 441, 449, 451, 461, 464, 475, 479, 480, 492, 497, 498, 499
Anobiidae 530
Antilocarpa americana 203
Aphrophora saratogensis 395
Araucaria angustifolia 1253
Arbutus menziesii- Cortinarius zakii 520
Arbutus menziesii 520
Arceuthobium abietinum 450
Arceuthobium abietinum f. spp. *concoloris* 468
Arceuthobium americanum 455, 468
Arceuthobium campylopodium 468
Arceuthobium douglasii 468, 518
Arceuthobium laricis 468
Arceuthobium pusillum 465
Arceuthobium tsugense 468
Arceuthobium vaginatum subsp. *cryptopodum* 476, 526
Arceuthobium spp. 497, 517
Archips semiferanus 403
Aristida stricta 248, 256, 680
Armillaria mellea 401, 484, 502, 512, 513
Aroga argutiola 393
Arrhenodes minutus 318, 319
Artemisia abrotanum 182
Artemisia scopularum 150
Artemisia tridentata 72, 128, 150, 192, 246
Artemisia spp. 174, 175, 191, 193, 255
Ascomycetae 434, 478, 492, 511, 529, 530
Aspergillus niger 483
Aspergillus ustus 528
Asteraceae 639
Atriplex canescens 144, 194, 235, 253
Atriplex spp. 193, 255
Atta cephalotes 370, 371
Atta sexdens 371
Atta texana 369, 370, 371

B

Bacillus cereus 327, 505
Bacillus thuringiensis 399, 406, 408, 427
Baculovirus spp. 391
Basidiomycetae 434, 445, 456, 492, 511, 519
Betula alleghaniensis 67, 68, 508, 537, 642, 643, 644, 645, 677, 678, 724, 807
Betula lenta 489
Betula lutea 537
Betula papyrifera 508, 564, 677, 678, 807
Betula spp. 441
Blepharipa scutellata 409
Bostrichidae 530
Bouteloua curtipendula 30
Braconidae 390
Brevipalpus grandis 360
Bromus inermis 3, 4
Burestidae 363

C

Calocalpe undulata 416
Camarosporium spp. 384
Canis lupus 221, 231, 241
Carex exserta 185
Carya aquatica 503
Carya cordiformis 503
Carya glabra 489
Carya illinoensis 503
Carya ovata 503
Carya tomentosa 503
Carya spp. 364, 470, 480, 789, 790, 966, 1203
Cassia nicitans 86
Castanea dentata 897
Ceanothus velutinus 787
Cecidomyiidae 336
Celtis spp. 497
Cerambycidae 530
Ceratocystis ulmi 324, 325, 412, 413, 418
Cervus canadensis nelsoni 227
Cervus canadensis 242
Chamaecyparis lawsoniana 429
Chamaecyparis thyoides 647
Cheirodendron trigynum 448
Choristoneura biennis 377
Choristoneura conflictana 390
Choristoneura occidentalis 408
Choristoneura pinus 354
Choristoneura viridis 377
Chrysocharis laricinellae 376
Chrysosporium lignorum 531
Chrysosporium pruinosum 531
Chrysosporium spp. 531
Chrysothamnus nauseosus 166
Chrysothamnus spp. 193, 255
Chysocharis laricinellae 374
Cibotium spp. 448
Cicidostiba dendroctoni 343
Cleridae 331
Clostridium spp. 1249
Coeloides brunneri 402
Coleophora laricella 374, 376
Coleoptera 455
Compsilura concinnata 409
Coniferae 517
Conoiophora puteana 1184
Conophthorus banksianae 343, 344
Contortylenchus spp. 353
Coptotermes brevis 1239
Coptotermes formosanus 428, 1239
Coriolus versicolor 532
Cornus florida 782
Cornus spp. 470
Corthylus columbianus 318, 319
Corticium olivascens 502
Cortinarius zakii 520
Corylus californica 727

Corylus cornuta var. *californica* 795, 796
Cowania mexicana 180
Cronartium fusiforme 439, 453, 527, 1058
Cronartium ribicola 458, 459, 494, 495, 514, 515, 871
Cytospora decipiens 508
Cytospora spp. 507

D

Dactylis glomerata 38
Daldinia concentrica 508
Dendrocopos spp. 204
Dendrocorticium 471
Dendroctonus adjunctus 350, 386
Dendroctonus brevicomis 317, 349, 398
Dendroctonus frontalis 323, 331, 346, 365, 379, 407
Dendroctonus ponderosae 322, 332, 333, 356, 422, 423
Dendroctonus ponderosae Hopk. 355
Dendroctonus pseudotsugae 402, 414, 417
Dendroctonus rufipennis 378, 405, 417
Dendroctonus spp. 353
Dentocorticium 471
Digitaria eriantha 6
Dioryctria abietella 337
Dioryctria spp. 316, 336
Diplodea pinea 522
Diplotaxis parvicollis 348
Diplotaxis spp. 348
Dipodomys microps 220
Diprion similis 339
Diptera 455
Dothichiza spp. 384
Dothistroma pini 491
Dothistroma pini var. *keniensis* 491
Dothistroma pini var. *linearis* 491
Dothistroma pini var. *pini* 491
Dryocoetes spp. 353

E

Echinodontium tinctorium 435, 446
Enaphalodes rufulus 318, 319, 342, 345
Endoganaceae 454
Endogone mosseae 144
Endogone spp. 454
Endothia gyrosa 444
Ennomos subsignarius 338, 416
Enoclerus sphegeus 402, 417
Enterovirus spp. 391
Ephialtes ontario 375
Epinotia meritana 392
Eragrostis curvula 6, 28
Eucalyptus robusta 895
Eucalyptus saligna 846, 847
Eucalyptus spp. 684, 1240
Eucosma agricolana agricolana 358
Eucosma agricolana argentialbana 358
Eucosma barbara 358
Eucosma cocana 336
Eucosma ochreana 358
Eucosma pergandeana pergandeana 358
Eucosma smithiana 358
Eulophidae 390
Euocsma pergandeana flavana 358
Eurotia lanata 189, 193
Eutamias minimus 234

F

Fabacea 639
Fagus americana 1163
Fagus grandifolia 67, 68, 442, 508, 513, 643, 644, 645, 677
Fagus spp. 464
Felis concolor 221
Festuca arundinacea 28, 38, 42
Flindersia brayleyana 847
Fomes annosus 484
Fomes connatus 507
Fomes igniarius 467, 507
Fomes pini var. *abietis* 446
Fomes pinicola 445
Formica fusca 462, 463
Formicidae 345
Fraxinus americana 442, 489, 508, 537
Fraxinus pennsylvanica 638
Fraxinus spp. 464
Fungi imperfecti 437, 492, 517, 519, 528, 529, 530
Fusarium lateritium 437
Fusarium oxysporum 437
Fusarium solani 373
Fusarium spp. 462, 463, 466

G

Ganoderma applanatum 445
Gaylussacia 782
Gigaspora spp. 454
Glaxiella spp. 454
Gleditsia triacanthos 480
Gloeocapsa magma 528
Glomus spp. 454
Goes pulverulentus 318, 319
Goes tigrinus 318
Graphium spp. 507
Gymenospermae 456
Gymnospermae 441, 449, 475, 479, 482, 492, 498, 499, 535
Gymnosporangae 478

H

Hamamelis spp. 403
Haplopappus tennuisectu 253
Helicotylenchus dihystera 447
Hericium abietis 435
Heterocampa guttivitta 513
Heteropogon contortus 157
Holobasidiomycetae 457, 469, 478, 493, 528, 529, 530
Homobasidiomycetae 457, 469, 478, 493, 528, 529, 530
Hylobius pales 382, 415, 421, 424, 425
Hylurgops rugipennis 417
Hylurgops spp. 353
Hymenoptera 389, 455
Hypnaceae 475
Hypoxlyn rubiginosum 508

I

Ichneumonidae 390
Ilex glabra 680
Impatiens balsamina 710, 711, 712
Ips concinnus 417
Ips paraconfusus Lanier 327
Ips perturbatus 417
Ips pini 326
Ips spp. 331, 353
Iridovirus spp. 391
Irpex mollis 480
Irpex spp. 432
Itoplectis quadricingulatus 375

J

Juglans major 437, 470
Juglans nigra 437, 442, 726, 822, 849, 850, 855, 859, 903, 927, 940, 1164, 1173, 1176, 1208, 1223, 1233, 1236
Juglans spp. 691, 938
Juniperus virginiana 516, 730, 745
Juniperus spp. 55, 429, 1046

K

Kochia prostrata 255

L

Laeticorticium canfieldii 470
Laeticorticium durangensis 470
Laeticorticium mississippiensis 470
Laeticorticium 471
Laeticorticium spp. 470
Lambdina fiscellaria lugubrosa 416
Larix decidua 118
Larix laricina 50, 366, 501, 754, 1300
Larix leptolepis 366
Larix occidentalis 374, 376, 429, 474, 809, 832
Larix spp. 363
Laspeyresia spp. 320, 336
Leanothus velutinus 150
Lentinus lepideus 529
Lenzites saepiaria 445
Lenzites trabea 430, 528
Lepista nuda 502
Leptoglossus corculus 320, 334, 335, 336, 373, 688, 923
Lespedeza cuneata 42
Lespedeza stipulacea 28
Libocedrus decurrens 440
Liquidambar formosana 444
Liquidambar styraciflua 430, 433, 469, 528, 638, 647, 660, 817, 1203, 1238
Liriodendron tulipifera 433, 638, 647, 658, 660, 705, 781, 784, 811, 817, 818, 837, 853, 855, 859, 863, 1113, 1158, 1163, 1169, 1175, 1233, 1236, 1333

Lisum usitatissium 385
Lolium spp. 42
Lophodermella morbida 460
Lophodermium pinastri 485, 521, 523
Lophodermium spp. 484
Loranthaceae 461
Lotus corniculatis 38
Lyctidae 530
Lymantria spp. 372
Lynx canadensis 221

M

Malacosoma disstria 367
Martes spp. 221
Matsucoccus acalyptus 357, 400
Medetera aldrichii 402, 417
Melampsora medusae 921, 924
Meleagris gallopavo 217, 218
Merecium spp. 432
Metrosideros collina 1240
Metrosideros collina spp. *polymorpha* 448
Microtus spp. 234
Modicella spp. 454
Molothrus ater 354
Monodontomerus dentipes 339
Morus spp. 470
Myrica aspleniifolia 393, 394
Myrsine lessertiana 448

N

Nemoria rubrifrontaria 394
Neodiprion spp. 339
Neopeckia spp. 484
Neophasia menapia 399
Nepytia semiclusaria 336
Nitidulidae 345
Nyssa sylvatica 782

O

Odocoileus hemionus 202, 242
Odocoileus virginianus 216
Odocoileus spp. 232
Oncorhynchus spp. 200
Opuntia spp. 253, 254
Orgyia pseudotsugata 239, 352, 408, 410
Orgyia pseudotsugata McD. 426
Ostomidae 331

P

Pachylobius picivorus 382, 415, 421, 424
Paleacrita vernata 384, 385, 411, 416
Panicum spp. 680
Panthera pardus 221
Paralobesia palliolana 366
Parandra brunnea brunnea 318
Paranthrene palmii 345
Parasetigena agilis 409
Parasitylenchus spp. 353
Paromyscus maniculatus 234
Parus atricapillus 354
Parvovirus spp. 391
Passeriformes 208, 213
Paulownia tomentosa 1247
Penicillium daleae 142
Penicillium nigricans 142
Peniophora cinerea 502
Peniophora gigantea 484
Peniophora sanguinea 502
Peniophora tamaricicola 452
Peniophora tinctorius 502
Peniophora 'G' 531
Pennisetum glaucum 42
Pericopsis elata 1247
Perisoreus canadensis 465
Phaeocryptopus gaumanni 485
Phanerochaete allantospora 451
Phanerochaete arizonica 451
Phanerochaete chrysosporium 531
Phanerochaete salmoneolutea 451
Phanerochaete spp. 451
Phaseolus mungo 693, 694
Phellinus chrysoloma 446
Phellinus igniarius 467
Phellinus weirii 482, 483
Phialophora melinii 507, 508
Pholiota adiposa 435
Phomopsis juniperovora 516
Phoradendron bolleanum subsp. *pauciflorum* 340
Phoradendron spp. 497
Phycomycetae 434, 492, 511
Phyllophaga 348
Phyllophaga spp. 401
Physalospora obtusa 437
Phytophthora cactorum 437
Phytophthora cinnamomi 447, 448, 478
Picea abies 361, 665
Picea engelmanii 532
Picea engelmannii 105, 361, 378, 429, 637, 759, 760, 769, 809, 828, 832, 873, 878, 881, 1192
Picea glauca 361, 656, 700, 829, 1299
Picea glauca var. *densata* 852
Picea glehnii 361
Picea jezoensis 361
Picea mariana 361, 465, 642, 754, 1102, 1299
Picea pungens 485, 486, 524, 732, 759, 769, 815, 896
Picea rubens 643, 644, 645, 647, 1299
Picea sitchensis glauca glauca 361
Picea sitchensis 142, 361, 417, 519, 908, 1018
Picea xlutzii 361
Picea spp. 363, 405, 731
Pinus aristata 476, 899
Pinus attenuata 460
Pinus banksiana 343, 344, 354, 525, 656, 690, 698, 700, 829, 1120, 1148
Pinus caribaea 661, 915, 916, 920
Pinus clausa 797, 930
Pinus contorta 77, 105, 161, 321, 322, 332, 333, 387, 440, 455, 476, 681, 751, 756, 759, 760, 762, 809, 832, 873, 881, 1125
Pinus contorta var. *contorta* 937
Pinus contorta var. *latifolia* 1011
Pinus contorta var. *murrayana* 937
Pinus echinata 34, 228, 334, 335, 336, 433, 447, 757, 791, 793, 818, 834, 860, 861, 909, 919, 936, 1142
Pinus edulis 55, 357, 400, 1046
Pinus elliottii 557, 669, 670, 671, 791, 800, 821, 834, 893, 909, 913, 917, 919, 922, 935, 936, 939, 944, 951, 952, 953, 954, 1058, 1142, 1144, 1145, 1158, 1168, 1193, 1194
Pinus elliottii var. *elliottii* 316, 320, 337, 373, 433, 439, 527
Pinus engelmanii 476
Pinus flexilis 476
Pinus glabra 909
Pinus jeffreyi 440, 453, 809, 832
Pinus lambertiana 440, 539
Pinus massoniana 721, 1297
Pinus monticola 458, 459, 473, 474, 494, 495, 514, 515, 871, 945, 946
Pinus nigra 522, 745
Pinus oocarpa 920
Pinus palustris 34, 433, 722, 723, 747, 748, 749, 750, 798, 800, 804, 834, 835, 858, 917, 953, 954
Pinus ponderosa 11, 51, 98, 105, 137, 321, 348, 350, 356, 386, 398, 399, 419, 422, 423, 429, 453, 460, 468, 470, 522, 526, 536, 539, 681, 745, 751, 759, 761, 763, 769, 771, 774, 788, 809, 814, 827, 832, 840, 873, 876, 898, 914, 943, 946, 1013, 1014, 1050, 1156
Pinus ponderosa var. *arizonica* 476
Pinus ponderosa var. *scopulorum* 476, 539
Pinus pseudostrobus 920
Pinus radiata 453
Pinus regida 34
Pinus resinosa 25, 28, 29, 34, 395, 401, 485, 521, 525, 655, 656, 657, 689, 690, 700, 808, 825, 1300
Pinus rigida 647, 902
Pinus serotina 647, 909
Pinus strobiformis 476, 759, 769, 815
Pinus strobus 34, 122, 123, 130, 442, 462, 463, 647, 662, 812, 1300
Pinus sylvestris 29, 485, 509, 521, 522, 523, 706, 707, 720, 746, 892
Pinus taeda 6, 7, 34, 41, 59, 108, 122, 228, 323, 334, 336, 346, 425, 433, 439, 469, 479, 639, 647, 659, 668, 669, 682, 757, 764, 765, 791, 793, 798, 799, 800, 806, 818, 819, 821, 830, 834, 854, 860, 861, 862, 890, 901, 909, 919, 922, 925, 951, 952, 1058, 1131, 1158, 1170, 1203, 1204, 1244, 1245, 1276
Pinus tenuifolia 920
Pinus thunbergiana 936
Pinus virginiana 34, 39, 41, 647, 791, 818, 830, 900, 919, 928, 929
Pinus spp. 315, 320, 321, 327, 331, 332, 333, 339, 349, 363, 380, 382, 415, 421, 424, 478, 491, 510, 684, 782, 848, 923, 966, 1031
Pisolithus tinctorius 447, 479, 502
Pissodes fasciatus 402
Pissodes strobi 361
Pissodes terminalis 387

Pityophthorus confertus 321
Platanus acerifolia 701
Platanus occidentalis 41, 638, 752, 801, 817, 857, 1281
Platanus wrightii 531
Platygloea arrhytidiae 452
Platygloea mycophila 452
Platygloea peniophorae 452
Podocarpus spp. 667, 679
Podophyllum peltatum 640
Poecilia reticulatus 22
Polypodiaceae 475
Polyporus abietinus 445
Polyporus anceps 532
Polyporus dichrous 533
Polyporus hispidus 480, 481
Polyporus versicolor 532
Polyporus volvatus 445
Polyporus spp. 432
Polystictus versicolor 532
Populous tremuloides 1102
Populus alba 1252
Populus balsamifera 501
Populus deltoides 41, 501, 538, 638, 660, 703, 719, 755, 801, 905, 1067, 1068, 1069, 1252, 1281
Populus euramericana 501
Populus fremontii 719
Populus grandidentata 367, 390, 537, 719, 1067, 1068, 1069, 1210, 1223, 1249
Populus heterophylla 719
Populus nigra 709, 713, 1020, 1021
Populus robusta 709, 713
Populus tremuloides 58, 96, 187, 367, 390, 501, 637, 656, 657, 719, 759, 769, 792, 816, 1120, 1148, 1249, 1290
Populus trichocarpa 538
Populus 911
Populus spp. 431, 918, 921, 924, 1237, 1323
Poria incrassata 529
Poria laevigata 480
Poria monticola 1184
Poria spiculosa 480
Poria weirii 482, 483, 484
Poria spp. 432
Porthetria dispar 328, 329, 330, 351, 368, 372, 397, 406, 409, 427
Poxvirus spp. 391
Prionoxystus macmurtrei 318, 319, 345
Prionoxystus robiniae 318, 319, 345, 381
Prosopsis spp. 497
Prunus pennsylvanica 678
Prunus serotina 416, 894, 1209, 1223
Prunus spp. 416
Pseudohylesinus nebulosus 402
Pseudopityophtorus spp. 413
Pseudotsuga menziesii 17, 105, 142, 359, 363, 402, 410, 414, 417, 429, 485, 510, 518, 519, 520, 576, 664, 673, 674, 675, 683, 728, 809, 810, 826, 832, 866, 869, 891, 932, 933, 943, 1014, 1038, 1083, 1106, 1162, 1178, 1179, 1290, 1302, 1323, 1328, 1333
Pseudotsuga menziesii Franco 362, 426
Pseudotsuga menziesii var. *glauca* 352, 474, 769, 906, 907
Pteromalidae 390
Ptychogaster spp. 531
Purshia tridentata 161, 193
Purshia spp. 255
Pygocryptus coryopsis n. spp. 388
Pygocryptus echthroides curentus n. subsp. 388
Pygocryptus echthroides echthroides 388
Pygocryptus echthroides 388
Pygocryptus erugatus n. spp. 388
Pygocryptus exilis n. spp. 388
Pygocryptus exochus n. spp. 388
Pygocryptus grandis 388
Pygrocyptus echthroides oribasus n. subsp. 388
Pythium spp. 478

Q

Quercus alba 477, 504, 512, 672, 803
Quercus coccinea 672, 1294
Quercus falcata 1203
Quercus falcata var. *pagodaefolia* 802
Quercus gambelii 150
Quercus garryana 520
Quercus kellogii 497
Quercus marilandica 782
Quercus muehlenbergii 803
Quercus nigra 660, 803, 843
Quercus phellos 481, 660, 802
Quercus rubra 453, 477, 504, 512, 717, 753, 758, 820, 831, 1163, 1174
Quercus shumardii 803, 1233
Quercus velutina 477, 489, 512, 672, 1158, 1226, 1227
Quercus spp. 318, 319, 330, 342, 345, 364, 403, 411, 413, 442, 464, 470, 480, 638, 647, 648, 784, 790, 966, 1181, 1238, 1315, 1333

R

Reovirus spp. 391
Reticulitermes flavipes 428, 429, 431
Reticulitermes spp. 430
Rhabdovirus spp. 391
Rhamnus purshiana 727
Rhizina undulata 484
Rhizobium japonicum 502
Rhizosphaera kalkhoffii 485, 486, 524
Rhyacionia buoliana 315, 380
Rhyacionia bushnelli 419
Rhyacionia frustrana 336
Rhyacionia neomexicana 347
Ribes nigrum 458, 459
Rogas spp. 384
Rubus parviflorus 795
Rubus spectabilis 795
Rubus spp. 680

S

Salix nigra 1252
Salix viminalis 702
Salmo gairdneri 200
Salmonids 201
Salvelinus malma 200
Salvia sonomensis 838
Scaphoideus luteolus 443
Scirrha pini 491
Scirrhia acicola 485, 509, 749
Sciurus aberti 179, 224
Sclerocystis spp. 454
Scleroderris lagerbergii 401, 525
Scolytidae 363
Scolytus multistriatus 324, 325, 412, 413, 418
Scolytus ventralis 340
Scolytus spp. 353
Sequoia sempervirens 429, 650, 734, 872
Serenoa repens 248, 256, 680
Setaria macrostachya 157
Sialia currucoides 239
Sialia mexicana 239
Sigmodon hispidus 196
Sitanion hystrix 246
Smilax glauca 184
Smilax rotundifolia 184
Smilax spp. 183
Solenopsis invicta 15, 723
Solenopsis richteri 15
Sorghum vulgare sudanese 42
Spaherularia spp. 353
Sphyrapicus varius varius 724
Spizella passerina 354
Sporobolus airoides 45
Sporotrichum pruinosum 531
Sporotrichum pulverulentum 531
Stegonosporium ovatum 513
Strix varia 212
Symphoricarpos oreophillis 255

T

Tachinidae 390
Tamiasciurus hudsonicus 465
Tarsonemidae 379
Taxodium distichum 429
Telenomus alsophilae 364
Temnochila chlorodia 402
Terminalia superba 1247
Tetyra bipunctata 320, 334, 373
Thanasimus undatulus 402
Thelephora terrestris 447, 479, 502
Thermomonospora fusca 1262
Thuja occidentalis 50, 700, 754
Thuja plicata 474, 1302
Tilia americana 564
Tomentella brunneorufa 472
Tomentella kentuckiensis 472
Tomentella spp. 472
Toona australis 847
Trechispora brinkmanii 484
Trichocladium canadense 508
Trichoderma viride 493
Trichoderma spp. 482
Trichogrammatidae 390
Trogodytes aedon 239
Tsuga canadensis 442, 501
Tsuga heterophylla 142, 519, 634, 1018
Tsuga mertensiana 775
Tsuga spp. 363

Tuber spp. 511
Tubercularia ulmea 384
Tylenchorhynchus claytoni 447

U

Ulmus alata 443
Ulmus americana 324, 325, 412, 413, 418, 442, 443, 1252
Ulmus crassifolia 443
Ulmus pumila 384, 385
Ulmus rubra 443
Ulmus serotina 443
Ulmus thomasi 443
Uniola laxa 195
Uniola sessiliflora 195
Ursus americanus 230
Ursus spp. 221

V

Vaccinium membranaceum 651
Vaccinium parvifolium 727
Vaccinium spp. 680
Veluticeps berkeleyi 502
Verticicladiella wagnerii 510
Viburnum alnifolium 644
Virola spp. 1247
Viscaceae 461
Viscum album 497, 498
Vitis spp. 654

X

Xyela gallicaulis 336
Xyletinus peltatus 433
Xylosandrus germanus 437
Xysticus apachecus 348

Z

Zapus princeps 234

KEYWORD INDEX

The first number(s) following the index term refers to the narrative statement in the *Research Accomplishments 1975* report. Numbers in parentheses refer to the publication list.

A

abiotic disease **199** (*466*)
abnormal wood (*1221*)
abscisic acid **587** (*706*)
absorption **13, 701, 731** (*19, 1214, 1274*)
acetone extract **278** (*337*)
acetylene reduction technique **175** (*446*)
acid paste **630** (*950, 952*)
acid precipitation (*149*)
acorns **542** (*803*)
acoustics **92, 750** (*742, 1312*)
acrylamide gels (*699*)
adhesives **703** (*1195, 1196, 1197, 1198, 1213, 1316, 1317, 1318, 1334*)
adsorption (*1237, 1292, 1293*)
advance reproduction **405** (*758*)
adventitious roots (*695, 696, 697*)
aerial delivery **147, 150** (*577, 580, 583, 595*)
aerial drift **555** (*786*)
aerial photography **29, 48, 170, 379, 618, 625** (*98, 158, 159, 167, 168, 169, 170, 171, 173, 210, 317, 879, 882, 883*)
aerial seeding **12, 546, 676** (*17, 819, 1131, 1147*)
aerial spraying **40, 295, 298, 302, 303, 313, 314, 555, 556** (*239, 396, 397, 399, 406, 408, 410, 426, 427, 786, 787*)
aesthetics **38, 60, 62, 681** (*208, 270, 272, 293, 294, 1124*)
AFFIRMS program **137** (*555, 596*)
age-class distribution (*650*)
age-specific density **259** (*343*)
air classifier **730** (*1273*)
air drying **691** (*1163, 1173, 1190*)
air pollution **16, 17, 18, 19, 20, 21, 120, 121, 197, 206** (*464, 492, 534, 535, 536, 537, 538, 539, 540, 546, 560, 562, 568, 662*)
air quality **110, 120, 121, 123, 148, 149** (*535, 544, 546, 560, 561, 562, 563, 566, 568, 569, 573, 607, 614*)
air tankers **145, 146, 147, 150** (*583, 588, 595, 597, 598*)
air transportation hazards **141** (*581*)
alder **508** (*475, 667, 679*)
aldrin **311** (*401*)
algae **755** (*528*)
algorithms **271, 611** (*296, 341, 871*)
alkali pulping **733** (*1259*)
alkali sacaton (*45*)
alkali treatment **723** (*1260, 1278*)
alligator juniper **378** (*54*)
allowable cut **442** (*1034, 1054*)
alternate hosts **188** (*458*)
ambrosia beetles **223, 763** (*363, 432*)
amenities **62** (*272, 275*)
American beech **102, 213** (*508, 644*)
American elm **131, 272** (*324, 325, 412, 413, 418, 564*)
amino acids **734** (*1262*)
anatomy **178, 578, 585, 631, 694** (*520, 701, 703, 954, 1220, 1277*)
animal damage **57, 566, 569, 571, 574** (*250, 722, 725, 727, 728*)
animal feed **721** (*1255, 1258*)
animal weights **49** (*241, 267*)
animals **201** (*465*)
antelope (*203*)
anthracnose **321** (*822*)
anthraquinones **198** (*516*)
antiaggregative pheromones **294, 304, 305** (*402, 405, 417*)
antibiotic production **214** (*478*)
antigens **216** (*502*)
ants **208** (*462, 463*)
Appalachian hardwoods **421, 424, 426** (*214, 770, 778, 780*)
apple orchards **185** (*498*)
aquatic habitat (*87*)
aquatic organisms **330** (*14, 154, 199, 201*)
aquifer **328** (*152*)
aromatic hydrocarbons (*1283*)
arsenic **11, 704** (*13, 1165*)
arthropods **223** (*363*)
artificial regeneration **410, 512, 517, 519, 522, 524, 530, 534, 536, 537, 570, 603, 632, 633, 634** (*729, 752, 766, 808, 812, 815, 820, 828, 837, 841, 846, 857, 891, 892, 898*)
asexual reproduction **651, 674** (*896, 897, 900, 902, 908, 936*)
ash content **701** (*1214, 1281*)
aspect (*704*)
aspen **231, 263, 374, 417, 492, 560, 636, 721, 757, 765** (*52, 58, 96, 101, 187, 367, 390, 431, 637, 656, 657, 769, 792, 816, 1067, 1068, 1069, 1120, 1121, 1210, 1223, 1237, 1249, 1255, 1323*)
assistance programs (*1027*)
Atlantic-white-cedar **434** (*647*)
atmospheric conditions **120, 148, 466** (*74, 546, 606, 607, 627*)
attitudes **76, 83, 113** (*292, 304, 554*)
attractants **169, 209, 229, 234, 237, 289, 306, 762** (*315, 326, 369, 377, 380, 414, 430, 489*)
auxins **583, 588, 589, 590, 591, 593** (*693, 695, 696, 697, 707, 709, 710, 711, 712, 713*)
avalanches **6, 7, 370, 371** (*107, 126, 131, 132, 138, 143*)

B

backfires (*567, 575*)
bacteria **11, 165, 175, 196, 197, 212, 324, 734, 755** (*13, 150, 441, 446, 449, 490, 492, 504, 507, 528, 1249, 1252, 1262*)
baits **278, 288, 306, 762** (*337, 371, 414, 430*)
balbo rye **476** (*42*)
baler (*1071*)
ball milling (*1258, 1264*)
balloon logging (*551, 1146, 1149*)
balsam fir **102, 742** (*644, 1299*)
balsam woolly aphid **227** (*360*)
band mills **690** (*1230*)
bark **209, 684, 701, 764** (*488, 489, 514, 515, 999, 1062, 1063, 1065, 1066, 1070, 1071, 1134, 1168, 1169, 1170, 1199, 1214, 1226, 1227, 1244, 1245*)
bark beetles **223, 240, 256, 297, 307, 655** (*327, 353, 363, 398, 423, 920*)
bark spreading equipment (*1064*)
bark wood separation **242** (*322, 1120, 1121, 1148*)
barred owl (*212*)
basal area **247, 487, 488, 565, 580, 598, 604, 614** (*122, 386, 674, 675, 704, 705, 793, 858, 862, 863*)
basswood **131** (*564*)
beams **699** (*1246, 1316*)
bedding **505, 506** (*670, 671*)
bedload **360, 361** (*82, 83*)
bedrock **347** (*110, 145*)
beetles **237, 245, 284, 319, 761** (*323, 326, 350, 407, 433*)
bending strength **736, 741, 744, 747, 748** (*1282, 1287, 1300, 1301, 1309, 1324, 1325, 1329*)
benefit cost analysis **438, 439, 449, 681** (*1025, 1026, 1045, 1124*)
Benlate **315** (*424*)
benomyl (*523, 524*)
bentonite **471** (*33*)
berryfield **99** (*651*)
best opening face **696, 698** (*1161, 1187, 1188, 1189, 1216, 1217*)
bibliography **83, 413, 577** (*292, 691, 695, 696, 697, 762, 836, 1105, 1222*)
bimolecular reaction **317** (*404*)
bioassays **36, 237** (*14, 200, 326, 413*)
biochemical oxygen demand **329** (*153*)
biochemistry (*686, 687, 708*)

bioethanomethrin **299, 300, 302** (*403, 411, 426*)
biological control **219, 230, 280, 283, 287** (*331, 339, 365, 375, 447, 452*)
biological damage (*1095*)
biological data (*205*)
biological oxygen demand (*1123*)
biological potential **602** (*854*)
biological treatment **734** (*1262*)
biomass **124, 496, 501, 505, 684** (*77, 122, 123, 576, 659, 671, 678, 1244*)
biosynthesis (*1266*)
bird habitat **37** (*206*)
bird predation **264** (*354*)
birds **201** (*217, 465*)
bitterbrush **26** (*161*)
black bear (*230*)
black capped chickadee **264** (*354*)
black cherry **301, 639** (*416, 894, 1209, 1223*)
black gum **562** (*782*)
black jack oak **562** (*782*)
black locust (*781*)
black oak **494** (*672, 1226, 1227*)
black spruce **201, 403, 742** (*465, 754, 1299*)
black stain **187** (*510*)
black walnut **163, 321, 528, 529, 568, 600, 638, 665, 692, 693, 702** (*437, 726, 822, 849, 850, 855, 859, 903, 927, 940, 1164, 1171, 1172, 1173, 1176, 1208, 1219, 1223, 1225, 1236*)
blackberry **188** (*458*)
blight **291** (*522*)
blister rust **611** (*871*)
blood chemistry (*231*)
blue spruce **202, 517** (*486, 524, 732, 815*)
blue-green algae **755** (*528*)
bluegrass (*113*)
bluestem **30** (*164, 165*)
board density **731** (*1274*)
boating **65, 76** (*279, 304*)
bogs **363** (*47, 48, 49*)
bolts **687** (*993, 1177, 1203*)
bonding **703, 727, 728** (*1198, 1288, 1291, 1329*)
bonding strength (*1195, 1196, 1197, 1269, 1315, 1323, 1334*)
borax (*1279*)
Bordeaux mixture **200, 204, 291** (*485, 509, 522, 524*)
boring (*1321*)
botany **595** (*640, 715*)
bound water **707** (*1235*)
Bowen ratio (*135*)
branch diseases **197** (*492*)
branches **351** (*130*)
branchwood **719** (*1275*)
breeding **282, 576, 660, 672** (*382, 689, 690, 856, 913, 931, 934, 941, 943*)
brevicomin **238, 297** (*349, 398*)
brick veneer **738** (*1305*)
bridge design **350, 741** (*60, 1300, 1320*)
brightness **723** (*1260*)
bristlecone pine **662** (*899*)
brood development **245** (*350*)
brooding **45** (*218*)
brown headed cowbird **264** (*354*)
brown rots **174, 221, 754** (*445, 457, 469, 1263*)
brown spot needle disease **200, 204, 408** (*485, 509, 749, 917*)
browse **566, 570, 574** (*166, 215, 228, 234, 260, 261, 266, 727, 728, 729*)
brush **119, 428, 717** (*547, 633, 635*)
brush control **33, 56, 58, 138, 344, 345, 428, 555** (*90, 94, 192, 201, 246, 254, 594, 635, 783, 786, 794*)
brush conversion **376** (*128*)
buckling **702** (*1219*)
building codes **751** (*1092, 1303*)
building design (*1224*)
building materials **749, 751, 771** (*1077, 1303, 1304, 1331*)
building trends (*1112*)
bulk density **3** (*7*)
bur oak **131** (*564*)
burning **403, 428** (*556, 635, 754*)
burning costs (*548*)
burning index **458** (*626*)
burning methods **120, 129** (*546, 549*)
burroweed (*253*)
butylene oxide **724** (*1285*)

C

cabins **709** (*1174*)
cable logging **357, 689** (*79, 141, 551, 1129, 1155*)
cacodylic acid **11, 308** (*13, 412, 413, 422*)
caffeic acid (*475*)
CALCOMP **130** (*565*)
calculators **465** (*620*)
California hazel **557, 558** (*795, 796*)
callus tissue **593** (*709, 713, 835*)
calorimeter **751** (*1303*)
cambium **585, 597** (*701, 720*)
campground layout **85** (*280, 287*)
campground regulations **77** (*306*)
campgrounds **23, 73, 74, 90** (*24, 288, 291, 302, 311*)
camping **65, 68, 73, 76, 77, 89** (*279, 280, 281, 302, 304, 305, 306*)
cankers **163, 167, 196, 197, 199, 208, 218, 293** (*437, 444, 462, 463, 466, 480, 481, 490, 492, 514, 515, 525*)
cankerworm hosts **252** (*385*)
canoeing **65, 68, 72** (*279, 280, 281, 283, 303*)
canopy (*77, 215, 291, 617*)
cant sawing **687, 698** (*1203, 1216, 1217*)
canyon maple **63** (*269, 285, 286*)
captafol **293** (*525*)
carbaryl **302, 315** (*424, 426*)
carbohydrate stabilizers **732** (*1271, 1278, 1279*)
carbohydrates **207** (*487*)
carbon cycle (*449*)
carbon dioxide **498, 573** (*666, 714*)
Caribbean pine **650** (*915*)
carnivores (*221*)
carotenoids (*916*)
carpenterworm **290** (*381*)
carrying capacity (ecological) (*209*)
carrying capacity (recreational) **65, 75, 78, 87** (*279, 284, 295, 307, 310, 312*)
carrying capacity (social) **90** (*284, 311*)
catalysts **732** (*1271*)
cattle **53, 54** (*248, 257, 259, 260, 261, 262, 267*)
cell structure **691, 694, 718** (*1163, 1220, 1221, 1223, 1276*)
cellophane **725** (*1256*)
cellulases **734, 754** (*469, 1258, 1262*)
cellulose **155, 733, 754, 757** (*431, 469, 602, 603, 611, 1258, 1259, 1264*)
census survey methods **48** (*210, 212, 242*)
chaining **58** (*254*)
chaparral **136, 157, 344, 345, 453** (*57, 89, 90, 94, 114, 584, 608, 1032, 1044*)
char yield (*603*)
charring rate (*1327*)
check dams **9** (*8*)
chelates (*1272*)
chemical analysis **210, 234, 735** (*109, 380, 477, 1283, 1295*)
chemical composition **566, 574** (*727, 728, 1281, 1294*)
chemical control **33, 173, 233, 293, 299, 311, 314, 318, 562** (*192, 316, 374, 397, 401, 403, 412, 421, 523, 524, 525, 782, 794*)
chemical residues **298** (*20, 396*)
chemical treatments **121, 677, 720, 724** (*21, 568, 1152, 1183, 1184, 1224, 1254, 1282, 1285, 1310, 1326, 1327*)
chemicals **13** (*19, 21*)
cherry scallop-shell moth **301** (*416*)
cherrybark oak **541** (*802, 1238*)
chinkapin oak **542** (*803*)
chip storage **722, 723, 756** (*531, 1260, 1289, 1296*)
chipping **687, 710, 778** (*1061, 1107, 1120, 1121, 1130, 1134, 1141, 1148, 1151, 1203, 1205, 1222*)
chipping sparrow **264** (*354*)
chips **394, 718, 723** (*988, 1000, 1063, 1074, 1075, 1076, 1123, 1134, 1168, 1169, 1226, 1227, 1245, 1260, 1276, 1279*)
chitinase (*512*)
chlorophyll (*916*)
chloroplast pigments (*488*)
chlorosis **197** (*492*)
chlorothalonil **200, 204, 292, 293** (*485, 509, 521, 523, 524, 525*)
Choctawhatchee sand pine **669** (*797, 930*)
choke cherry **301** (*416*)
chokers **689** (*1155*)
Christmas tree plantations **204** (*509*)
Christmas trees **96, 202, 224, 292, 661** (*362, 486, 491, 521, 523, 524, 746, 937, 1073, 1105*)
chromatography **649, 735** (*166, 191, 909, 1252, 1283, 1295*)
chromosomes (*172, 698, 700*)
cis-verbenol **240** (*327*)
clearcutting **44, 326, 342, 404, 410, 411, 517, 561, 569** (*75, 78, 147, 204, 229, 237, 725, 755, 757, 766, 767, 781, 784, 815, 1130*)
cliffrose (*180*)
climate **468** (*73*)
climax forest (*66*)
clones **21** (*172, 187, 662*)

cloning **521, 666** (*840, 938*)
cloud cover **398** (*1017*)
cloud seeding **466, 467** (*601, 606*)
coal mine spoils **470, 471, 473, 474, 475, 476, 477, 478, 479, 481, 482, 483, 484** (*27, 28, 29, 30, 32, 33, 34, 35, 36, 37, 38, 39, 41, 42, 43, 44*)
cold injury **529** (*850*)
combustion **155, 751, 752** (*602, 603, 611, 1303, 1304, 1311, 1327*)
commercial forest land **443** (*982, 986, 990, 1003, 1024, 1039, 1059*)
commercial thinning **441, 447** (*1031, 1038*)
commercial timber **713** (*1167, 1240*)
communication principles **83** (*292*)
competition **4, 435, 474, 524, 537, 548, 614** (*6, 41, 345, 654, 808, 831, 837, 863*)
composite lumber (*1101, 1232, 1234*)
computer display (*592*)
computer mapping **618, 619** (*879, 884*)
computer models **373, 374, 612, 685** (*100, 101, 303, 873, 1133, 1231*)
computer programming **9, 336, 439, 465, 616, 625, 696, 697, 698, 715** (*8, 53, 81, 296, 620, 622, 870, 882, 1010, 1026, 1037, 1127, 1135, 1160, 1177, 1188, 1216*)
computer use **133, 134, 135, 137** (*555, 586, 589, 591, 596, 698, 1037*)
concrete slabs **746** (*1298*)
cone harvest **173, 510, 545, 658** (*316, 821, 823, 932*)
cone insects **274** (*336*)
cone production **406** (*747*)
conelet abortion **274, 276, 654** (*334, 336, 688, 923*)
cones **278, 291** (*337, 522*)
coneworms **173, 278** (*316, 337*)
conflagrations **125, 136** (*559, 584*)
Coniferous Forest Biome **97** (*634*)
conifers **14, 105, 165, 181, 183, 185, 191, 203, 220, 331, 340, 351, 366, 403, 413, 417, 428, 517, 557, 558, 582, 620, 759** (*105, 115, 123, 129, 130, 142, 429, 440, 441, 468, 470, 473, 474, 475, 498, 499, 519, 535, 635, 637, 684, 698, 735, 754, 762, 769, 795, 796, 815, 887*)
conservation (*737*)
construction (*1224, 1320, 1334*)
construction industry (*1213*)
construction materials (*1092, 1112*)
consumer preferences **776** (*286, 1108*)
consumption **769** (*1085*)
containerized seedlings **196, 215, 478, 509, 512, 513, 520, 522, 526, 539, 540** (*29, 59, 162, 479, 490, 798, 800, 824, 825, 839, 841, 842, 846, 847, 1066*)
containers **737** (*1218, 1284*)
contaminants **23** (*24, 201, 1269*)
contract procedures **683** (*1111, 1185*)
control release formulation **169** (*315*)
Cooley spruce gall aphid **224** (*362*)
cooperatives (*1100*)
copper (*1272*)
copper chromate **705** (*1159*)
corporate demands (*1035*)
corrosion **146, 720** (*588, 1254*)
corrugating medium **729** (*1270, 1280*)
cortex (*721, 1297*)
cortical monoterpene **649** (*909*)
cost analysis **138, 150, 380, 624, 716** (*137, 551, 594, 595, 888, 1135, 1150*)
cost-sharing **440** (*1027, 1028*)
cotton rat **50** (*196*)
cottonwood **437, 502, 532, 579, 647** (*638, 660, 719, 801, 905, 1281*)
coumaric acid (*475*)
crab spiders **254** (*348*)
crawl spaces **746** (*1298*)
creeping sage **511** (*838*)
creosote **699, 704** (*1165, 1183, 1246, 1283*)
crook **679, 680** (*1202, 1204*)
crossties (*1072*)
crown density **374, 628** (*101, 951*)
crown differentiation **549** (*830*)
crown dominance **405, 567** (*724, 758*)
crown weights **124** (*576*)
cruising (*1250*)
crystallinity (*1258*)
cubic measurements **485** (*867*)
cubic volume **485** (*867*)
cull **162** (*435, 1018*)
culvert design **350** (*60*)
cure time **703** (*1198*)
cuticle **13** (*19*)
cutter head **677** (*1152*)
cutting energy **687** (*1203*)
cutting width **708** (*1175*)
cuttings **377, 534, 535, 591, 593** (*144, 183, 187, 709, 711, 713, 752, 805, 817*)
cycloheximide **584, 592** (*694, 1020, 1021*)

D

dam design **9** (*8*)
damage appraisal **139** (*590*)
danger rating system **133** (*586*)
data collection **34** (*2, 127, 160, 596, 956, 1010*)
data retrieval **135** (*591, 883*)
data storage **135** (*591*)
DDT **40, 302** (*20, 21, 239, 426*)
debarking **710** (*1120, 1121, 1148, 1151*)
debris **6, 7, 142** (*131, 132, 582*)
decay **165, 174, 212, 213, 218, 220, 762** (*430, 438, 441, 442, 445, 451, 470, 471, 472, 480, 493, 496, 504, 506, 507, 508, 1018*)
decay resistance **724** (*1285*)
decisionmaking **78, 79, 80, 82, 86, 88, 130, 438, 439, 449, 618, 622, 623, 696** (*226, 290, 299, 307, 308, 309, 314, 565, 879, 881, 889, 1025, 1026, 1045, 1048, 1146, 1188*)
deckboards **765** (*1068, 1069, 1315*)
decomposition **11, 25, 329** (*13, 23, 136, 140, 153, 1252*)
decontamination (*1269*)
decouplers **750** (*1312*)
deer **43, 46, 566, 569, 570, 574** (*202, 215, 216, 225, 229, 232, 233, 235, 242, 725, 727, 728, 729*)
defect sensing **162, 696, 697** (*435, 1160, 1188*)
defects **162, 697, 739** (*435, 1156, 1160, 1192, 1308*)
defibration (*1222*)
deflection **740, 744** (*1301, 1313*)
defoliation **202, 205, 207, 222, 231, 236, 244, 252, 263, 266, 267, 295, 302** (*328, 329, 330, 352, 367, 385, 388, 390, 392, 408, 426, 486, 487, 513, 524*)
deforestation **325, 337** (*91, 136, 148*)
deformations **743** (*1314*)
degradation **165, 705, 720, 722, 723, 756, 757, 758, 758** (*431, 441, 529, 529, 530, 531, 1159, 1254, 1260, 1266, 1289*)
degrade **171, 679** (*318, 319, 1091, 1190, 1202, 1228*)
degree of use **57** (*250, 258*)
dehydration (*203, 1286*)
dehydrogenases **203** (*456, 499*)
delignification **721, 732, 733** (*1255, 1259, 1271, 1272*)
delivery systems **147, 150** (*583, 595*)
Delphi technique **78** (*307*)
demand **69** (*275, 277, 1080, 1082*)
demographic change **770** (*1081, 1082*)
dendrology **107, 108** (*730, 734, 738, 739*)
dendrometry **616** (*870*)
densitometry **164** (*436*)
density **725, 728** (*856, 1247, 1256, 1261, 1288, 1321, 1328*)
density gradient (*1264, 1265*)
depolymerization **732** (*1271, 1279*)
design criteria **743, 745, 747, 748** (*1302, 1314, 1324, 1325, 1330*)
detection survey **169, 170, 234** (*315, 317, 380*)
Dexon **315** (*424*)
diameter growth **405, 549, 561, 601, 614** (*758, 784, 830, 853, 863*)
diameter increment **488, 544, 548, 554, 559, 598, 599, 604, 628** (*674, 761, 788, 818, 831, 852, 858, 862, 951*)
diameter measurement **613** (*781, 876*)
diaphorase (*505*)
dieback **206** (*464*)
diet evaluation (*259*)
diffusion (*68, 1233, 1237*)
diformazan (*505*)
digestibility **721** (*1255, 1258*)
digitizing **135** (*591*)
dimension lumber **708** (*1175, 1177, 1225, 1242, 1243, 1316, 1319*)
dimension material yield **600** (*855, 859*)
dimensional stability **693, 701, 724** (*1172, 1214, 1234, 1247, 1285, 1322, 1329*)
dimethoxon analogs **317** (*404*)
dioxin **10** (*22*)
direct seeding **12, 403, 473, 504, 506, 516, 530, 538, 543, 546, 549, 568, 571, 572** (*17, 34, 669, 670, 722, 723, 726, 754, 799, 806, 812, 813, 814, 819, 830*)
directories (*842, 1094*)
discoloration **165, 213** (*438, 441, 442, 506, 507, 508*)
disease control **163, 197, 204, 218, 291, 292, 293** (*437, 480, 481, 491, 492, 509, 521, 522, 523, 524, 525*)
disease diagnosis **270** (*368*)

219-692 O - 76 - 10

disease resistance **642, 652, 656** (*890, 921, 922, 924*)
diseases **174, 176, 181, 211, 272, 321, 455** (*324, 445, 460, 468, 503, 822, 1058*)
dispersion characteristics (*577, 580*)
dispersion equipment **145** (*598*)
dissemination **202** (*455, 481, 486*)
dissolved oxygen concentration **329** (*153*)
distillation (*1283*)
distribution **232** (*376, 640*)
ditches **362** (*50*)
DNA synthesis **576** (*689, 690*)
dogwood **562** (*782*)
Douglas-fir **12, 124, 178, 187, 192, 222, 224, 226, 302, 304, 330, 340, 441, 456, 486, 487, 488, 515, 556, 566, 574, 606, 608, 609, 633, 658, 659, 660, 701, 714, 751** (*17, 105, 154, 352, 359, 362, 402, 410, 426, 484, 510, 518, 520, 576, 663, 664, 673, 674, 675, 683, 727, 728, 787, 809, 810, 826, 832, 866, 868, 869, 891, 932, 933, 943, 1014, 1038, 1083, 1106, 1162*)
Douglas-fir beetle **294, 304, 306** (*402, 414, 417*)
Douglas-fir tussock moth **222, 295, 302** (*352, 408, 410, 426*)
Douglure **306** (*414*)
drainage **319, 362** (*48, 49, 50, 407*)
drop patterns **145** (*598*)
drought **346, 348** (*1, 53, 64, 108*)
drug injection (*227*)
dry matter production **503** (*668*)
dry ravel (*114*)
dryers **730** (*1273*)
drying **692, 725, 728** (*1164, 1176, 1181, 1237, 1238, 1249, 1256, 1288*)
drying defects (*1171, 1200, 1201, 1249*)
drying methods **158, 678, 699** (*609, 610, 1143, 1228, 1246*)
drying rates **678** (*1113, 1143, 1171, 1200, 1201, 1238*)
durability **700** (*1182, 1234, 1239*)
Dutch elm disease **272** (*324, 325, 412, 413, 418*)
dwarf mistletoe **181, 192, 193, 194, 195, 201, 239, 247, 322** (*340, 386, 450, 455, 461, 465, 468, 476, 517, 518, 526*)
dynamic analysis (*1154*)
dynamic events (*1277*)

E

earth flows **6** (*131*)
earth pressure **712** (*1138*)
eastern cottonwood **641** (*918*)
eastern larch **260** (*366*)
eastern redcedar (*730*)
eastern subterranean termite **759, 760** (*428, 429*)
eastern white pine **21, 434** (*647, 662*)
ecology **41, 50, 108, 179, 248, 253, 256, 416, 432** (*196, 223, 347, 353, 357, 434, 641, 652, 737, 739, 763*)
econometric models **456** (*1033, 1083, 1106*)
economic analysis **439, 441, 766** (*89, 797, 1026, 1033, 1035, 1038, 1057, 1084*)
economic guidelines **444** (*1043*)
economic impact **166, 171, 421, 424, 454, 455** (*318, 319, 439, 770, 778, 1036, 1055, 1056, 1058*)
ecosystems **413** (*222, 762*)
ecotypes **489, 634** (*681, 898, 904*)
ectendomycorrhizae **178, 215** (*479, 520*)
ectomycorrhizae **178, 214, 215, 216, 579** (*447, 478, 479, 502, 520, 719*)
edge gluing (*1317*)
edgings **615** (*864*)
education **109** (*550*)
egg mass density **266, 267** (*328, 329, 330*)
egg-laying preferences **761** (*433*)
elasticity **700, 726, 728, 740, 741, 742, 747** (*1182, 1268, 1288, 1290, 1299, 1300, 1313, 1317, 1324, 1332*)
electrical resistance (*438, 442*)
elevational limits **101, 433** (*642, 643, 645*)
elk **46** (*219, 225, 227, 242, 243*)
elm **168** (*443*)
elm spanworm **281, 301** (*338, 416*)
embryos **551, 667, 670** (*686, 687, 843, 929, 935*)
emergence **245, 272, 282** (*324, 350, 382*)
emissions **121, 123** (*568, 569*)
employment **775** (*1055, 1059, 1074, 1075, 1076, 1118*)
endangered species **49, 105, 675** (*231, 241, 735, 926*)
endomycorrhizae **182, 215, 579** (*454, 479, 719*)
endrin **12** (*17*)
energetics (*211*)
energy **678, 683, 725** (*1134, 1143, 1185, 1256*)
energy balance **461, 469** (*70, 135, 619*)
energy conservation (*572*)
energy source **682** (*1089, 1097, 1186*)
Engelmann spruce **255, 340, 372, 515, 519, 621** (*76, 105, 378, 637, 809, 828, 832, 878, 1192*)
engineering **5** (*106*)
environment **119, 410, 438, 717** (*294, 547, 633, 766, 1025*)
environmental data **365** (*124*)
environmental education **83, 84, 89** (*292, 305, 313*)
environmental groups (*1048*)
environmental impact **26, 40, 60, 67, 68, 110, 357, 362, 398, 426, 689** (*16, 50, 141, 161, 239, 270, 273, 281, 566, 780, 1017, 1126, 1133, 1146, 1155, 1183*)
environmental law (*1052*)
environmental planning **336** (*81*)
environmental quality **5, 22, 149, 152** (*25, 106, 294, 600, 614*)
environmental stress **205, 206** (*464, 513*)
environmental tree culture **94** (*743, 744*)
enzymes **203, 317, 583** (*404, 499, 505, 512, 693, 1258*)
epichlorohydrin **724** (*1285*)
equipment **152, 164, 555** (*436, 600, 786, 950, 1304*)
equipment testing (*79*)
erodibility index **1** (*10*)
erosion **1, 2, 3, 4, 5, 6, 7, 8, 325, 344, 345, 347, 349, 357, 367, 374, 472, 482** (*6, 7, 9, 10, 11, 12, 27, 31, 56, 57, 61, 62, 63, 79, 84, 90, 94, 101, 106, 110, 114, 115, 116, 131, 132, 136, 139, 141, 148*)
erosion control **9, 474, 476** (*8, 41, 42*)
erosion hazard (*151*)
ERTS-1 imagery **34, 395, 398** (*158, 160, 1009, 1017*)
esophageal fistula (*259*)
etiology **211** (*503*)
eucalyptus **644, 713** (*895, 1240*)
European elm bark beetle **272** (*324, 325, 412, 413, 418*)
European larch **358** (*118*)
European mistletoe **185** (*498*)
European pine shoot moth **169, 234** (*315, 380*)
evapotranspiration **331, 337, 364, 373, 374** (*48, 58, 91, 100, 101, 115, 121, 129, 135*)
experience levels **64, 71** (*276, 282*)
experimental ranges (*247*)
export sales **116** (*541*)
exposure **469, 705** (*70, 1159, 1239*)
extinction **273** (*383*)
extractives **203, 209, 693, 735, 759, 760** (*428, 429, 456, 488, 489, 499, 500, 1172, 1253, 1261, 1295, 1296, 1297*)

F

failure **703** (*1137, 1198, 1277*)
fall cankerworm **279, 301** (*364, 416*)
false spider mite **227** (*360*)
farm buildings (*1112*)
farm tractor **677** (*1152*)
fasteners **720** (*1254, 1332, 1333*)
fatty acids **285, 735** (*346, 1295, 1296*)
feasibility analysis **682, 710** (*1151, 1136*)
fecundity **248, 761** (*342, 347, 433*)
feeder-root pathogens **214** (*447, 478*)
feeding deterrents **315** (*424*)
feeding habits **45, 275** (*218, 335*)
feeding territories (*214*)
feeding trials (*211*)
fences **375** (*134, 1072*)
fermentation **734** (*1262*)
fertility **490** (*342, 676*)
fertilization **2, 21, 99, 475, 486, 490, 493, 495, 496, 497, 502, 506, 507, 528, 529, 639** (*11, 16, 28, 63, 163, 186, 449, 651, 658, 660, 661, 662, 663, 664, 665, 670, 676, 677, 678, 849, 850, 894*)
fertilizers **4, 24, 25, 487, 501, 566** (*6, 18, 21, 23, 26, 659, 673, 675, 683, 728*)
ferulic acid (*475*)
fescue (*264, 291*)
fiber bonding **725** (*1256, 1257*)
fiber content (*233*)
fiber production **503, 532, 603, 652** (*668, 801, 857, 921, 924, 1157*)
fiber products (*1061*)
fiber properties **719, 726, 728** (*1267, 1268, 1269, 1275, 1277, 1280, 1288, 1290*)
fiber recovery (*1280*)

fiber saturation point **693** (*1172, 1236, 1292*)
fiberboard **737, 768** (*1088, 1213, 1284, 1326*)
fibril angle (*1267*)
field planting **215** (*479*)
films **112, 164** (*436, 542*)
fir engraver bark beetle **239** (*340*)
fire behavior **114, 125, 130, 136, 148, 154, 155, 156, 157, 160** (*545, 559, 565, 584, 602, 603, 605, 607, 608, 611, 612, 613*)
fire control **109, 114, 132, 152, 152, 458** (*545, 550, 587, 600, 600, 626, 1032*)
fire danger **133, 458** (*586, 626*)
fire danger rating **137, 160** (*53, 555, 596, 612*)
fire ecology **66, 128, 140, 151, 153, 161** (*274, 585, 593, 599, 615, 616*)
fire effects **128, 139, 140, 149, 151, 153, 161, 355, 368, 404** (*46, 88, 96, 561, 585, 590, 593, 599, 614, 615, 616, 755*)
fire fighting chemicals **143** (*578*)
fire hazard **117, 125, 127, 144, 681** (*543, 552, 553, 559, 579, 1032, 1124, 1125*)
fire losses (economic) **138, 139** (*590, 594*)
fire management **66, 114, 128, 130, 134, 135, 136, 150, 151, 153** (*274, 545, 565, 584, 585, 589, 591, 592, 593, 595, 599*)
fire models **157** (*580, 608*)
fire performance **151, 751, 752, 753** (*599, 1303, 1306, 1310, 1311, 1326, 1327*)
fire physics **154** (*605*)
fire prediction **156** (*613*)
fire prevention **109, 112, 113, 115, 134** (*542, 550, 554, 558, 589*)
fire protection **138** (*594*)
fire reports **66** (*274, 592*)
fire retardants **121, 143, 145, 146, 147, 150, 751, 752** (*14, 18, 568, 577, 578, 580, 583, 588, 595, 598, 1072, 1282, 1303, 1310, 1311, 1326, 1327*)
fire statistics **135** (*591*)
fire use **111, 114, 123, 129, 140, 149** (*544, 545, 549, 557, 560, 561, 563, 567, 569, 572, 614, 616, 1032*)
fire weather **129, 457, 458, 459, 464** (*549, 560, 622, 623, 624, 625, 626, 631*)
fireline construction **152** (*600*)
firing techniques **129, 132** (*549, 567, 575, 587*)
firs **244** (*392*)
fish habitat (*197, 198*)
fish kills **36** (*14, 200*)
fishing **81** (*87, 297*)
flakeboard **687, 701** (*1191, 1203, 1205, 1206, 1214*)
flakes **700** (*1182, 1193, 1199, 1242, 1243*)
flame spread **752** (*1282, 1310, 1311, 1326*)
flammability **158** (*602, 609, 610*)
flash fuels **136** (*584*)
flat crush test **729** (*1270*)
flax **252** (*385*)
flood discharge **350** (*60*)
flood peaks **343, 381** (*51, 55*)
flood tolerance **437** (*638*)
floods **350, 359** (*60, 114, 119*)
flooring costs (*1079, 1103, 1104*)
flooring markets (*1103, 1104*)
flourides **17** (*534*)
flow duration curves (*145*)
flow dynamics **156, 350** (*60, 613*)
flowering **27, 406, 489, 553, 639, 648, 658** (*188, 681, 747, 833, 894, 910, 932*)
flowers **660** (*943*)
fluoride **704** (*535, 1165*)
fly ash treatment **477** (*38*)
flyhead acetylcholinesterase **317** (*404*)
FOCUS simulation model **134** (*589*)
fog **459** (*624, 627*)
foliage **351** (*122, 123, 130*)
foliage diseases **196, 197** (*490, 492*)
foliar analysis **490, 491** (*655, 676*)
foliar fertilization (*673, 683*)
foliar sampling **495** (*658*)
foliar spraying **562** (*782, 783*)
folk medicine (*640*)
food habits **44, 47, 581** (*204, 209, 217, 224, 229, 685*)
food plants **31, 46, 47, 104, 435** (*178, 209, 211, 222, 224, 225, 229, 639, 654*)
food reserves **207** (*487*)
forage **28, 30, 33, 43, 51, 53, 54, 59, 378, 381, 448, 574, 681** (*51, 54, 163, 164, 165, 166, 181, 185, 192, 215, 216, 249, 251, 252, 255, 257, 258, 260, 261, 262, 265, 268, 727, 1050, 1124*)
forage condition (*267*)
forage digestibility (*233*)
forage preferences (*191, 229, 235, 249, 259*)
forage production (*235, 248, 256, 1046*)
forbs **57, 378** (*54, 162, 233, 249, 250*)
forest acreage **382, 384, 385, 389** (*957, 958, 959, 961, 962, 964, 965, 968, 969, 970, 974, 978, 980, 983, 984*)
forest diseases **163, 165, 183, 184, 188, 189, 190, 191, 192, 193, 194, 195, 198, 199, 200, 204, 212, 217, 218, 219, 220, 221, 292, 322, 323, 754** (*437, 438, 441, 442, 448, 450, 451, 452, 453, 455, 457, 458, 459, 466, 469, 470, 471, 472, 473, 476, 480, 484, 485, 494, 504, 506, 509, 514, 516, 517, 518, 519, 521, 526, 527, 535*)
forest disturbances **395** (*1009*)
forest economics **711** (*1153*)
forest ecosystem **66, 97, 99, 192, 246, 325, 356, 419, 425, 429, 432, 602, 717** (*16, 92, 93, 148, 197, 240, 274, 387, 518, 633, 634, 636, 651, 652, 774, 779, 854*)
forest floor **492** (*136, 657*)
forest income **450, 711** (*1051, 1153*)
forest industries (*992, 996*)
forest inventory **383, 388, 389, 395, 396, 442, 451, 616, 618, 619, 623, 624, 779** (*159, 266, 870, 879, 884, 885, 888, 889, 956, 957, 958, 963, 964, 967, 971, 972, 973, 974, 977, 978, 983, 984, 985, 1003, 1009, 1010, 1012, 1015, 1016, 1022, 1023, 1034, 1047, 1119*)
forest land (*84, 981, 1057*)
forest land ownership **443** (*266, 990, 1039, 1052, 1054, 1059*)
forest management **86, 246, 247, 307, 369, 374, 413, 416, 417, 442, 444, 446, 447, 452, 618, 619, 717** (*101, 112, 314, 386, 387, 423, 562, 572, 633, 730, 762, 763, 769, 772, 879, 884, 942, 979, 1031, 1032, 1034, 1036, 1037, 1042, 1043, 1048, 1052, 1053*)
forest productivity (*917, 986*)
forest products **383, 454, 711, 768, 769** (*963, 1056, 1085, 1087, 1088, 1106, 1140, 1153, 1215*)
forest products industries **392, 454, 767** (*990, 1004, 1005, 1007, 1056, 1059, 1074, 1075, 1076, 1078, 1086*)
forest protection **321** (*822*)
forest regulation **446** (*1042, 1054*)
forest resources **429, 450, 454, 711** (*240, 636, 1051, 1056, 1078, 1153*)
forest survey **52, 104, 166, 384, 387, 388, 389** (*263, 439, 639, 785, 959, 960, 961, 971, 974, 980, 985, 986*)
forest taxation (*1040, 1041*)
forest tent caterpillar **263** (*367*)
forest types **107, 386, 433, 621** (*115, 642, 738, 878, 976, 981*)
forestry business organization (*1052*)
Forestry Incentives Program **440** (*1024, 1028*)
Formosan sweetgum **167** (*444*)
fourwing saltbush **377** (*144, 194, 235, 253*)
fractionation (*1264, 1265*)
free water **335, 707** (*103, 1235*)
frequency distribution (*592*)
frontalin **297** (*398*)
frost damage **430, 489, 536** (*653, 681, 820*)
frost heaving **516, 517** (*813, 814, 815*)
fructose **195, 209** (*450, 489*)
fruits **581** (*190, 685*)
fuel management **119, 125, 130, 142, 144, 153** (*547, 559, 565, 579, 582, 593*)
fuel models **160** (*612*)
fuel moisture **114, 158, 458** (*86, 545, 609, 610, 626*)
fuel oil (*1089*)
fuel reduction **136, 681** (*584, 1124, 1125*)
fuelbreak (*1032*)
fuels **125, 127, 129, 142, 143, 144, 153, 159, 160** (*543, 549, 559, 578, 579, 582, 593, 604, 612, 1089, 1097*)
fundilan (*524*)
fungicides **196, 197, 200, 204, 291, 292, 321, 705** (*485, 490, 491, 492, 509, 521, 522, 523, 524, 822, 1159*)
fungus damage **763** (*432*)
furniture industries **709** (*1001, 1174, 1218*)
fusiform rust **166, 217, 323, 455, 642, 656, 657** (*439, 453, 527, 890, 922, 925, 1058*)

G

galactose **209** (*489*)
gallberry **499** (*680*)
game management **81** (*205, 297*)

gamma radiation **432** (*652*)
Gardona **314** (*397*)
genetic improvement **27, 486, 640, 644, 647, 672, 673** (*188, 663, 664, 805, 895, 905, 911, 941, 944, 948, 1033*)
genetic traits **107, 225, 636, 641, 646, 663** (*361, 738, 816, 912, 918, 946*)
genetic variation **479, 634, 635, 671, 675** (*39, 898, 904, 906, 907, 926, 939*)
genetics **521, 638, 641, 643, 650, 651, 665, 672, 675** (*172, 186, 187, 285, 698, 840, 893, 896, 897, 900, 902, 903, 908, 913, 915, 918, 926, 927, 931, 934, 940, 941*)
gentisic acid (*475*)
geographic variation **576, 643, 651** (*689, 893, 902*)
geology **369, 429** (*112, 151, 636, 883*)
gibberellic acid (*175, 184*)
gibberellins **586, 587, 588** (*702, 706, 707*)
girdling **207, 315** (*424, 487*)
glucose **195, 209** (*450, 489, 1281, 1286*)
gluing (*1196, 1232, 1316, 1318*)
glulam **747, 748** (*1324, 1325*)
gold chloride (*325*)
gold tagging (*325*)
grade recovery (*1251*)
grading systems (*1162*)
grafting **521, 649, 659, 666, 669** (*840, 909, 930, 933, 938*)
grand fir **162, 227, 340, 412, 430** (*105, 360, 435, 653, 775*)
granitic soils **1, 2** (*10, 11*)
granuloses **228** (*391*)
grapevine **435** (*654*)
grasses **35, 59, 85, 160, 378, 470, 475** (*1, 3, 4, 28, 30, 36, 54, 157, 163, 233, 249, 252, 253, 287, 291, 548, 612*)
grasslands (*258*)
gray jays **201** (*465*)
grazing **28, 53, 54, 56, 711** (*155, 163, 181, 185, 229, 232, 246, 248, 253, 257, 262, 1153*)
grazing capacity (*245, 268*)
grazing effects **359** (*113, 119*)
grazing habits **57** (*250, 267*)
grazing intensity (*258, 260, 261*)
grazing land (*1098*)
grazing systems **59** (*252, 264*)
Great Plains Forestry **251** (*384*)
green ash **437** (*638*)
green budworm **229** (*377*)
green liquors **722, 723** (*1260, 1289*)
greenbrier (*183, 184*)
greenhouse **520** (*839*)
ground cover **85** (*181, 255, 287*)
groundline treatments **704** (*1165, 1184*)
groundwater **23, 328, 363, 712** (*24, 47, 48, 49, 152, 1138*)
growing stock (*970, 977*)
growth **2, 415, 423, 487, 504, 505, 506, 540, 547, 577, 599, 604, 605** (*11, 669, 670, 671, 675, 691, 760, 776, 791, 800, 810, 852, 858, 860*
growth analysis **575, 594** (*716, 718*)
growth curves **500, 609** (*682, 868*)
growth prediction **414, 419, 423, 494, 559, 601, 613, 614, 620** (*672, 700, 759, 774, 776, 788, 853, 863, 876, 886, 887, 904, 986, 1022*)
growth rate **372, 567** (*76, 724, 1281*)
growth regulators **587, 588, 597** (*706, 707, 720*)
growth requirements **575, 583** (*693, 718*)
growth response **554** (*761, 1036*)
guaiac (*1263*)
guardrails **739** (*1308*)
gully control **9** (*8*)
gum collection **677** (*1152*)
gum yield **628, 630** (*951, 952*)
guppies **10** (*22, 201*)
gypsum board **749, 750** (*1312, 1331*)
gypsy moth **266, 267, 268, 269, 270, 312, 313, 314** (*328, 329, 330, 351, 368, 372, 397, 406, 409, 427*)

H

H-MAFFS **147** (*583*)
habitat classification (*212, 214*)
habitat management **39, 45, 560** (*213, 214, 218, 792*)
habitats **34, 98, 103, 414, 620, 717** (*160, 633, 646, 649, 759, 772, 887*)
handcraft marketing (*1100*)
handsheets **726** (*1257, 1268*)
hardboard **751, 767, 768, 769** (*1085, 1086, 1088, 1282, 1290, 1303, 1328, 1329*)
hardwood defoliator **268, 269, 279, 281, 300, 313, 314** (*329, 338, 351, 364, 372, 397, 406, 411, 427*)
hardwood dimensions (*1207, 1208, 1209, 1210*)
hardwood management **435, 532** (*654, 801*)
hardwood utilization **709** (*1157, 1174*)
harmonic analysis **346, 465** (*64, 620*)
harvest equipment **447, 677, 689, 706** (*79, 139, 1031, 1121, 1122, 1128, 1129, 1133, 1134, 1135, 1141, 1142, 1144, 1145, 1146, 1152, 1154, 1155, 1199, 1206*)
harvest operations **403, 404, 410, 716** (*754, 755, 766, 1130, 1133, 1136, 1141, 1149, 1150, 1154*)
hauling **772** (*1115, 1126*)
hazard reduction **111, 115, 122, 126** (*548, 557, 558, 567, 571, 574*)
hazardous sites **6** (*131*)
haze **141** (*581*)
head capsule measurements **262** (*394*)
headrigs **687** (*1203*)
heart rot **175** (*446, 481*)
heartwood **692, 693** (*1164, 1172, 1223*)
heat release **751, 752** (*1303, 1304, 1311*)
heat transfer **737** (*1284*)
height growth **405, 518, 549, 637** (*758, 827, 830, 914*)
height increment **487, 514, 544, 548, 598, 620** (*675, 781, 818, 831, 848, 862, 887*)
height/age curves **494** (*672*)
helicopter logging **118** (*551, 570, 1133, 1135, 1146, 1149*)
helicopters **147, 676** (*583, 1147*)
hematology (*231*)
hemicelluloses **732, 733, 757** (*431, 1259, 1271, 1279*)
herbage production **33, 46, 57, 58, 59, 344, 378, 381, 475, 476** (*28, 42, 51, 54, 90, 192, 195, 203, 225, 247, 250, 252, 253, 254, 256, 260, 261, 267*)
herbarium specimens (*733*)
herbicides **10, 33, 36, 308, 343, 344, 345, 376, 378, 453, 555, 556, 557, 558, 562, 563, 564** (*20, 21, 22, 54, 55, 90, 94, 128, 136, 192, 200, 201, 412, 422, 782, 783, 786, 787, 789, 790, 794, 795, 796, 1044, 1046*)
heritability **626, 635, 646, 649, 663, 664, 671** (*904, 906, 907, 909, 912, 939, 945, 946, 947*)
hibernation (*230*)
hickories **211, 218, 563, 564** (*480, 503, 789, 790*)
high elevation forests **519, 608** (*828, 869*)
highway plantings **208** (*462, 463*)
highway posts **739** (*1308*)
hiking **65, 75** (*279, 295*)
histology **16, 178** (*495, 514, 520, 536, 539*)
hobblebush **102** (*644*)
hollocelluloses (*1292*)
home construction **745, 746** (*1212, 1298, 1330*)
home range **32** (*179, 212, 221, 232*)
homeostasis **325** (*148*)
homeowner surveys (*1095*)
homozygous pine plantlets (*835*)
Honduran pines **655** (*920*)
honeylocust **218** (*480*)
horizontal shear **686** (*1132*)
horticultural plants **203** (*499*)
host species (*461*)
host-parasite interactions **189** (*459, 515*)
hosts **181, 182, 185, 204, 283** (*339, 454, 468, 484, 495, 498, 509*)
household formation **770** (*1081, 1082*)
household trash **730** (*1273, 1280*)
housing costs **771** (*1077, 1079*)
housing demand **770, 771** (*1077, 1081, 1082*)
huckleberry **99, 562** (*651, 782*)
humidity **257** (*395*)
humus (*140*)
hunting **81** (*297*)
hybridization **640, 661** (*911, 934, 937*)
hydraulic transport (*1123*)
hydroelectric power **333** (*102*)
hydrogen peroxide **193, 754** (*469, 517*)
hydrology **325, 334, 363, 365, 373, 374** (*47, 48, 58, 96, 100, 101, 114, 124, 125, 148*)
hydrolysis (*1258*)
hydrometeorology **352** (*133*)
hydroxybenzoic acid (*475*)
hydroxylation (*533*)
hypocotyls **589** (*712*)

I

ice damage **208** (*462, 463*)
identification **100, 216, 231** (*390, 502, 731*)

image processing (*1277*)
imbricatoloic acid (*1297*)
immobilization (animal capture) (*221, 227*)
impact tests **739** (*1068, 1308*)
imported fire ant **15, 572** (*15, 723*)
imports (*1140, 1180*)
imprinting **45** (*217, 218*)
improvement cutting **418, 565** (*771, 793*)
inbreeding **646** (*912, 934*)
incubation (*198*)
indicator species **52, 397** (*263, 1019*)
indolylacetic acid **583, 584, 589, 590, 592, 597** (*693, 694, 710, 712, 720, 1020, 1021*)
infection **322** (*506, 526*)
infestation **249, 253, 310** (*356, 357, 419*)
infiltration **23, 332, 358** (*24, 56, 111, 118, 156*)
infiltrometer (*113, 156*)
information systems **82, 619** (*290, 884*)
injection system **573** (*714*)
injury **14** (*440, 1221*)
inoculation **163, 181, 217** (*437, 453, 468, 493, 506, 507*)
inorganic chemicals **705** (*1159*)
input-output model **454** (*1056*)
insect behavior **237, 243** (*321, 326*)
insect biology **243, 285, 655** (*321, 346, 920*)
insect control **232, 234, 238, 241, 253, 257, 258, 297, 305, 310, 313, 762** (*332, 344, 349, 357, 376, 380, 395, 398, 405, 419, 427, 430*)
insect damage **172, 274, 653, 654, 668, 763** (*320, 336, 432, 688, 919, 923, 928, 1239*)
insect distribution **287** (*365*)
insect mortality **269** (*372*)
insect populations **170, 223, 231, 263, 264, 268, 273, 280, 305** (*317, 329, 331, 351, 354, 363, 367, 383, 390, 405*)
insect trapping **229** (*377*)
insecticides **15, 40, 296, 298, 299, 300, 301, 302, 303, 308, 310, 316, 317, 762** (*15, 239, 396, 399, 403, 404, 411, 412, 415, 416, 419, 422, 425, 426, 430*)
insects **172, 174, 205, 209, 235, 236, 251, 255, 262, 290, 304** (*320, 378, 381, 384, 388, 389, 394, 402, 445, 455, 489, 513, 530*)
insolation **336** (*81*)
instrumentation **339, 353, 464** (*80, 85, 625*)
insulation **737, 738, 746, 753** (*1284, 1298, 1305, 1306*)
insulation board **749, 751, 767, 768, 769** (*1085, 1086, 1088, 1303, 1331*)
insurance **138** (*594*)
intensive culture **442, 486, 490, 499, 502, 532, 552, 639** (*660, 663, 664, 676, 680, 801, 834, 856, 894, 1033, 1034*)
interest groups **86** (*314*)
interlock devices (*1129*)
intermediate cuttings **565, 600** (*793, 855, 859*)
introduced pine sawfly **283** (*339*)
introduced species **185** (*461, 498*)
investments **382, 439, 440** (*965, 1026, 1027, 1028, 1057*)
iodides **732** (*1271, 1272*)
ironwood **131** (*564*)
irrigation **22, 468, 470** (*25, 30, 73, 74*)
isoenzymes (*692*)
isolation **179, 212** (*434, 493, 504*)
isopachs (*145*)
isotherms (*1293*)
isozymes **203** (*499*)

J

jack pine **258, 259, 293** (*343, 344, 525, 656, 686, 687, 708, 1120*)
jack pine budworm **264** (*354*)
jack pine tip beetle **258, 259** (*343, 344*)
Japanese larch **260** (*366*)
Jeffrey pine **515** (*809, 832*)
joining (*1222*)
joint strength (*1332, 1333, 1334*)
jumping cholla **58** (*253, 254*)
juvenile characteristics **100, 673** (*731, 944, 1281*)

K

kangaroo rat (*220*)
Kentucky bluegrass (*291*)
kerf **615** (*864*)
kiln drying **678, 679, 680** (*1113, 1143, 1171, 1173, 1176, 1200, 1201, 1202, 1204*)
knots (*1253*)
koa **713** (*1240*)
kraft paper (*1269*)
kraft pulping **723, 726** (*1142, 1257, 1260, 1268*)
kurtosis (*621, 629*)

L

labor **380, 775** (*137, 1098, 1118*)
labor law (*1052*)
laboratory rearing **279, 281** (*338, 342, 364*)
laboratory techniques **315** (*231, 424, 699*)
laccase (*1263*)
laccolith (*145*)
laminated beams **747, 748** (*1317, 1318, 1319, 1324, 1325*)
laminated lumber (*1315, 1316, 1320*)
land development (*169, 170, 171, 1055*)
land management **623** (*889, 1048*)
land use classification **29** (*167, 168, 170, 171, 173, 1140*)
land use planning **29, 87, 88, 101, 349, 369, 373, 374, 438, 443, 449, 471, 623, 625, 711, 715** (*33, 61, 100, 101, 112, 167, 168, 169, 170, 171, 173, 298, 299, 310, 312, 643, 645, 880, 882, 889, 1025, 1039, 1045, 1048, 1055, 1127, 1140, 1153*)
land valuation (*986, 1057*)
landforms **93, 94** (*740, 743, 744*)
landscape management (*240*)
landscape planning **60, 62, 63** (*269, 270, 272, 294*)
landscapes **60, 61, 90** (*270, 271, 311*)
landslides **6, 7, 367** (*114, 116, 131, 132*)
larch casebearer **232, 233** (*374, 376*)
larch moth **260** (*366*)
large aspen tortrix **231** (*390*)
larval development **222, 233, 243, 246, 250, 252, 261, 278, 281, 282, 284, 286** (*321, 323, 337, 338, 342, 345, 352, 355, 374, 379, 382, 385, 387, 393*)
lasers (*1161*)
lathes **687** (*1203*)
lava flow **184** (*448*)
leaching (*1123*)
leaf area **353, 580** (*80, 705*)
leaf biomass **436** (*648*)
leaf initiation (*686, 687*)
leaf press (*5*)
leaf rust **652** (*921, 924*)
leaf-cutting ants **288** (*370, 371*)
leaf-footed pine seedbug **275, 276** (*334, 335*)
least squares regression **617** (*874, 875*)
legislation **320, 446** (*420, 1042*)
legumes **508, 584** (*86, 667, 679, 694*)
length-of-run **456** (*1083*)
lethal alleles **667, 668** (*928, 929*)
levoglucosenone (*602*)
life cycle **262** (*394, 491*)
life history **309** (*400*)
life tables **226** (*359*)
light (*175*)
light intensity **258** (*344*)
light scattering **725** (*1256*)
lightning **319, 466, 467** (*407, 601, 606*)
lightning fires **161, 467** (*601, 615*)
lightwood (*955*)
lignans (*1253*)
lignases (*532, 533*)
lignins **43, 757** (*216, 431, 532, 533, 1264, 1266, 1281, 1294*)
lime **475, 497** (*28, 677*)
linear regression **271** (*341*)
linolenic acid **281** (*338*)
lipids **284, 285** (*323, 346*)
liquids **707** (*1235*)
litter **309, 354, 358, 366, 436** (*18, 86, 118, 120, 140, 142, 400, 449, 648*)
livestock **57, 59, 359** (*119, 250, 252, 258, 264, 266, 1098*)
livestock management **51, 53** (*248, 257, 265, 267*)
load analysis **772** (*1115*)
loblolly pine **3, 4, 104, 166, 215, 348, 427, 434, 500, 501, 503, 504, 538, 539, 540, 543, 544, 545, 546, 547, 549, 552, 565, 598, 602, 605, 642, 645, 656, 657, 684, 732, 733** (*6, 7, 59, 108, 122, 140, 228, 439, 479, 639, 647, 659, 668, 669, 682, 764, 765, 791, 793, 798, 799, 800, 806, 818, 819, 821, 830, 834, 854, 860, 861, 862, 890, 901, 922, 925, 1131, 1170, 1244, 1245*)
lodgepole pine **26, 127, 241, 242, 246, 340, 374, 399, 401, 413, 415, 489, 515,**

622, 661, 681 (*101, 105, 161, 322, 332, 333, 387, 543, 681, 751, 756, 760, 762, 809, 832, 881, 937, 1011, 1124, 1125, 1191*)
lodgepole terminal weevil **246** (*387*)
log grading **696, 714, 779** (*1119, 1162, 1177, 1178, 1179, 1188, 1250*)
log rules **485, 615** (*864, 867, 1070*)
log storage **763** (*432*)
log transportation **772** (*12, 1115*)
loggers (*1094*)
logging **5, 26, 255, 716** (*84, 106, 151, 161, 229, 378, 1008, 1129, 1136, 1150*)
logging damage **407, 420** (*748, 768*)
logging economics **116, 447, 710, 773, 778** (*541, 551, 1031, 1099, 1107, 1151*)
logging operations **130, 391, 710, 778** (*565, 991, 1107, 1151*)
logging residues **62, 116, 329, 330, 600, 682, 683** (*63, 153, 154, 197, 198, 272, 541, 855, 859, 1008, 1061, 1125, 1130, 1170, 1185, 1186*)
logging systems **118, 426, 716** (*570, 780, 1134, 1146, 1150*)
logs **685, 697, 716, 769** (*1074, 1085, 1150, 1160, 1218, 1231*)
longleaf pine **406, 407, 408, 409, 533, 539, 540, 571, 572, 604, 629** (*722, 723, 747, 748, 749, 750, 798, 800, 804, 835, 858, 917, 953*)
lovegrass **4, 474, 476** (*6, 41, 42*)
lumber **392, 615, 697, 740, 747, 751, 758, 769** (*529, 864, 1004, 1005, 1007, 1072, 1085, 1113, 1160, 1187, 1226, 1227, 1245, 1303, 1307, 1313, 1324, 1334*)
lumber exports (*1074, 1075, 1076*)
lumber grading **773** (*1099, 1192, 1309, 1316, 1319*)
lumber prices **771** (*1077, 1190*)
lumber production **773** (*964, 1075, 1076, 1099, 1189, 1229*)
lumber sales (*1139*)
lumber yield **698, 708, 773** (*1099, 1168, 1169, 1175, 1177, 1181, 1192, 1207, 1208, 1210, 1216, 1217*)
lysis **754** (*469, 512*)

M

machine grading **740** (*1307, 1309, 1313*)
machining **687** (*1203, 1222, 1232, 1234, 1242, 1243, 1321*)
macrofungi **179** (*434*)
macrosporin **198** (*516*)
magnesium **507** (*665*)
malathion **301** (*416*)
mammals **431** (*234, 632*)
management planning **410, 452, 620** (*766, 880, 886, 887, 1053*)
maneb **200, 292, 293** (*485, 521, 523, 525*)
manganese **732** (*1271, 1272*)
mannose (*1286*)
maple syrup **626, 627, 776** (*285, 286, 947, 948, 949, 1089, 1097, 1108*)
maple syrup marketing (*1109*)
maples **300** (*411, 1177*)
mapping **135, 618** (*591, 879*)
market analysis **37, 74, 764, 766, 767, 768** (*206, 288, 1062, 1063, 1073, 1080, 1084, 1086, 1087, 1088, 1104, 1105, 1106, 1110, 1180, 1212, 1307*)
mass media **112, 113** (*542, 554*)
mass wastage **6, 7, 472, 484** (*31, 44, 131, 132*)
Masson pine (*721*)
mast **581** (*685*)
materials handling **683** (*1185*)
mathematical analysis **743** (*1314*)
mathematical models **1, 268, 698, 707, 737** (*10, 351, 623, 1015, 1016, 1187, 1216, 1235, 1284, 1309*)
mating behavior **272** (*217, 324*)
maturation **541** (*802*)
mayapple (*640*)
measurement techniques **339, 341, 352, 353, 468, 509, 605, 612, 684, 736** (*69, 71, 73, 77, 80, 85, 93, 95, 97, 104, 133, 156, 289, 438, 824, 860, 861, 873, 1022, 1096, 1244, 1287, 1302*)
mechanical barriers **214** (*478*)
mechanical control (plants) **58** (*254, 256*)
mechanical properties **718, 723, 741, 742** (*1260, 1276, 1299, 1300, 1329*)
mechanical pulps **718** (*1276*)
melting (*104*)
mensuration **620** (*887*)
mercaptoethanol (*456*)
mercerization **733** (*1194, 1259*)
mesoscale **463** (*630*)
mesquite **58, 59** (*252, 253, 254*)
metabolic inhibitors **348, 590** (*108, 710*)
metabolism (*695, 696, 697*)
meteorology **461, 465, 466, 467** (*601, 606, 617, 619, 620, 622*)
methane formation (*1252*)
methanol **733** (*1259*)
methyl methacrylate monomer (*1232*)
methylcyclohexenone **294, 304, 305** (*402, 405, 417*)
methylthymol blue (*109*)
metric measurement **607, 612** (*865, 873, 877*)
mexacarbate **299, 300, 302, 303, 315** (*399, 403, 411, 424, 426*)
microbial insecticides **228, 270, 295, 313** (*368, 391, 406, 408, 427*)
microclimate **461, 469** (*70, 619*)
microfungi **183** (*519*)
microorganisms **15, 25, 165, 165, 174, 175, 212, 366** (*15, 23, 140, 142, 441, 441, 445, 446, 484, 496, 504, 505, 507*)
microscopy **699** (*1246*)
microwave techniques **158, 335** (*103, 609, 610*)
mill-length logs (*1179*)
millage assessment (*1040*)
milling **687** (*1203*)
minerals **213** (*508*)
mini-rotation **640** (*911*)
minimum cost paths (*296*)
mining operations **481, 482, 711** (*27, 43, 1153*)
mining regulations **484** (*44*)
mirex **15, 762** (*15, 430*)
mistletoe **185, 186, 192, 194, 322** (*461, 476, 497, 498, 518, 526*)
mites **286, 287** (*365, 379*)
mitotic cycle **576** (*689, 690*)
models **8, 55, 143, 154, 346, 381, 438, 452, 461, 463, 616, 633, 766** (*9, 51, 64, 96, 122, 123, 155, 244, 578, 605, 619, 622, 630, 870, 886, 891, 1025, 1053, 1084, 1128*)
moisture content **158, 174, 477, 531, 542, 678, 679, 680, 684, 691, 692, 693, 702, 707, 725, 728, 729, 738, 742** (*38, 445, 609, 610, 803, 851, 1113, 1143, 1163, 1164, 1172, 1173, 1200, 1201, 1202, 1204, 1219, 1233, 1235, 1237, 1244, 1256, 1257, 1261, 1270, 1288, 1292, 1293, 1299, 1305, 1321, 1322, 1333*)
moisture gradients **707** (*1235*)
moisture stress **191, 239** (*340, 473*)
moldy seed **277** (*373*)
Monitor **316** (*425*)
monitoring (*149*)
montane zone (*732*)
morphactin **589** (*712*)
morphogenesis (*181*)
morphology **30, 265, 591, 594, 595** (*59, 164, 165, 174, 202, 230, 358, 711, 715, 716*)
mortality **241, 242, 244, 254, 256, 259, 283, 295, 303, 412, 431** (*322, 332, 339, 343, 348, 353, 392, 399, 408, 632, 775*)
mosquitos (*201*)
motivation **72** (*283, 300*)
mountain hemlock **412** (*775*)
mountain maple **102** (*644*)
mountain pine beetle **241, 242, 249, 250, 307, 308** (*322, 332, 333, 355, 356, 422, 423*)
mountain whitethorn **428** (*635*)
mountainous terrain **352, 462, 463, 689** (*133, 628, 630, 1155*)
mulch **2, 475, 483, 518, 764** (*11, 28, 37, 45, 827, 1062, 1063, 1064, 1065, 1071*)
multiple use management **369, 381, 425, 435, 438, 450, 452** (*51, 112, 226, 240, 251, 275, 654, 779, 1025, 1046, 1051, 1052, 1053*)
MULTIPLOY **439** (*1026*)
multiproduct analysis **779** (*1119, 1156*)
multiresource management **52, 448, 622** (*263, 881, 1050*)
multispectral scanner **395, 398** (*1009, 1017*)
mung bean **583** (*693*)
mycology **182, 219, 220, 756** (*451, 452, 454, 470, 471, 472, 531*)
mycoparasitism **219** (*452*)
mycoplasma **168, 211** (*443, 503*)
mycorrhizae **178, 179, 180, 196, 197, 214, 215, 216, 377, 579, 582** (*144, 434, 447, 478, 479, 490, 492, 502, 511, 520, 684, 719*)
myrcene **297** (*398*)

N

nails **720** (*1117, 1254, 1318, 1332, 1333, 1334*)
natural beauty **63** (*269*)
natural catastrophes **619** (*884*)
natural range **105, 651** (*735, 896, 897, 900, 902, 908*)
natural regeneration **388, 399, 401, 404, 407, 408, 409, 411, 412, 415, 437, 565, 610** (*638, 748, 749, 750, 751, 755, 756, 760, 767, 775, 793, 872, 971*)
natural resources (*169, 170, 171, 737*)
naval stores **628, 629, 630, 677, 735** (*950, 951, 952, 953, 955, 1152, 1295, 1296*)
nectar **195** (*450*)
needle blight (*491*)
needle injury **16** (*536*)
needle necrosis **21** (*662*)
needleboard (*1194*)
needlecast **176, 202, 204, 292** (*460, 486, 509, 521, 523, 524*)
needles **100, 200, 226, 684** (*359, 485, 721, 731, 1170, 1244, 1297*)
nematodes **196, 197, 214, 256** (*353, 447, 478, 490, 492*)
nesting (*207*)
nestling survival **40** (*239*)
net volume equations (*966*)
neutron activation analysis (*325*)
newsprint **730** (*1273*)
niche **103** (*646*)
nitrogen **25, 498, 502** (*18, 23, 660, 666, 673, 683*)
nitrogen cycle (*449*)
nitrogen dioxide (*539*)
nitrogen fertilizers **99, 224, 488, 501, 566** (*362, 651, 659, 674, 728*)
nitrogen fixation **104, 175, 508** (*446, 449, 639, 667, 679*)
noble fir **609** (*868*)
noise abatement **93, 94** (*740, 743, 744*)
noise attenuation **92** (*742*)
nomenclature **228** (*391*)
nongame species **79** (*309*)
nonlinear regression (*966*)
nonmycorrhizal feeder roots (*447*)
nonresidential construction **768** (*1087, 1088*)
Norfolk Island pine **713** (*1240*)
northern red oak **536, 548** (*820, 831*)
northern white cedar **403** (*754*)
Norway spruce **507** (*665, 805*)
nucleopolyhedrosis virus **228, 269** (*372, 391*)
nursery **520** (*839*)
nursery diseases **197, 202, 293** (*486, 491, 492, 524, 525*)
nursery management **17, 531** (*534, 805, 842, 851, 856, 942*)
nursery practices **292, 524, 529, 582** (*521, 684, 808, 850*)
nursery stock **515** (*809, 810, 832*)
nutrient analysis **21, 102, 337, 495, 496, 497, 503, 721** (*91, 211, 229, 259, 644, 658, 662, 668, 677, 678, 1255*)
nutrient cycling **25, 149, 325, 356, 501** (*18, 23, 57, 92, 93, 148, 614, 659*)
nutrients **22, 24, 326, 581** (*25, 26, 147, 685*)
nutrition **284, 506, 507, 591, 594** (*163, 323, 665, 670, 711, 716*)

O

oak bark beetles (*413*)
oak leaf roller **299** (*403*)
oak timberworm **763** (*432*)
oak-hickory forest type **139** (*590*)
oaks **171, 210, 212, 218, 267, 299, 300, 437, 494, 561** (*240, 318, 319, 330, 403, 411, 477, 480, 504, 512, 638, 672, 784*)
odor response **237** (*326*)
ohia **184, 713** (*448, 1240*)
oldman wormwood (*182*)
oleoresins **628, 629, 630, 631** (*913, 951, 952, 953, 954, 955*)
optical planimeter **353** (*80*)
organic matter **11, 25, 354** (*13, 23, 56, 120, 136*)
organic phosphates (*1282*)
organic soils **363** (*47, 48, 49*)
ornamental plantings **167, 185** (*444, 461, 498*)
Orthene **316** (*425*)
overburden **470, 472** (*30, 31*)
overland flow **358** (*118*)
overstory **379, 407, 408** (*98, 291, 748, 749*)
oviposition **250, 251, 285** (*346, 355, 384*)
oxidant injury (*539*)
oxidation **329** (*153, 1266*)
oxydemetonmethyl (*412, 413*)
oxygen **498** (*666*)
oxygen demand **330** (*154*)
oxygen pulping **732** (*1271, 1272, 1278, 1279*)
oxygenation (*533*)
ozone **16, 17, 18, 20** (*534, 535, 536, 538, 539, 540*)

P

Pacific madrone **178** (*520*)
Pacific silver fir **97** (*634*)
packing **524** (*808*)
palatability (*166, 191, 249*)
pales weevil **282, 296, 315, 316, 318** (*382, 415, 421, 424, 425*)
pallets **687, 731, 765, 774** (*1067, 1068, 1069, 1090, 1091, 1114, 1116, 1117, 1203, 1205, 1218, 1274, 1315*)
panel products **749** (*1218, 1331*)
paper **728** (*1288*)
paper birch **213, 523** (*508, 807*)
paper honeycomb core **753** (*1306*)
paper mill fines **721** (*1255*)
paper properties **725, 726, 727, 733, 736** (*1256, 1257, 1257, 1259, 1267, 1268, 1287, 1291*)
papermaking (*1269*)
parana pine (*1253*)
parasites **181, 192, 193, 230, 232, 233, 236, 256, 259, 279, 283, 312** (*339, 343, 353, 364, 374, 375, 376, 388, 409, 468, 517, 518*)
parasitism **186, 192** (*461, 497, 518*)
parasitoids **231** (*390*)
particle orientation **700** (*1182*)
particleboard **687, 695, 700, 701, 751, 767, 768, 769** (*1085, 1086, 1088, 1101, 1182, 1191, 1193, 1195, 1196, 1197, 1203, 1205, 1212, 1213, 1214, 1242, 1243, 1247, 1248, 1303, 1322, 1323, 1328*)
particulate matter **17, 123, 325** (*148, 534, 556, 563, 569, 573*)
partridge pea (*86*)
party walls **750** (*1312*)
pasture lands **359** (*119*)
patch cuttings **46** (*99, 225*)
pathogens **184, 657** (*448, 925*)
payload capacity **118** (*570*)
peak flow **359** (*119*)
peat **363, 526** (*47, 825*)
peatlands (*48, 49*)
pecans **211** (*503*)
pectinase (*515*)
pellet counts (*209, 242*)
pelletized seed **676** (*1147*)
pentachlorophenol **704** (*1165, 1183*)
perception **61, 62** (*271, 272*)
performance testing **741, 744, 745** (*1300, 1301, 1330*)
permeability **691, 692** (*1163, 1164, 1171, 1241*)
peroxidase **584, 592** (*692, 694, 1020, 1021, 1263*)
peroxyacetyl nitrate (*539*)
personal contact **109** (*550*)
pest control industry **320** (*420*)
pest management **266, 309** (*328, 400, 688*)
pesticides **13, 25, 253, 295** (*18, 19, 20, 21, 23, 357, 408, 410*)
pH **25, 324, 356, 473** (*23, 34, 92, 150, 1195*)
phenolics **209, 588** (*456, 467, 475, 488, 489, 495, 707*)
phenology **536, 633** (*820, 891, 904*)
phenotypic selection **626** (*947*)
pheromones **169, 229, 234, 237, 238, 238, 240, 288, 289, 297, 306** (*315, 326, 327, 349, 349, 369, 370, 371, 377, 380, 398, 414*)
phloem necrosis **168** (*443*)
phloroglucinol (*475*)
phomopsis blight **198** (*516*)
phosphate mine spoils **472** (*31*)
phosphorus **502, 506** (*660, 670*)
photo-oxidation (*916*)
photointerpretation **395** (*158, 159, 1009*)
photoperiodic effects (*904*)
photorespiration **575** (*718*)
photosynthesis **573, 594** (*714, 716*)
phoxim **299, 300** (*403, 411*)
phylogeny **651** (*896, 897, 900, 902, 908*)
physiography **192** (*518*)
picnic shelters (*1110*)
picnic tables **709** (*1110, 1174*)
picnicking **89** (*305*)
pigmentation **213** (*508*)
piling (*1072*)
pine barrens **103** (*646*)

pine butterfly **303** (*399*)
pine needles (*1194*)
pine tip moth **310** (*419*)
pineland threeawn (*248, 256*)
pines **169, 172, 176, 187, 188, 217, 234, 243, 276, 283, 291, 315, 316, 318, 473, 493, 506, 514, 562, 631, 735** (*34, 215, 245, 315, 320, 321, 334, 339, 380, 421, 424, 425, 453, 458, 460, 510, 515, 522, 539, 661, 670, 782, 848, 954, 1295*)
pinyon **253, 309** (*357, 400*)
pinyon needle scale **253, 309** (*357, 400*)
pinyon-juniper type **343** (*55, 236, 1046*)
pipelines **362** (*50, 1123*)
pit gage (*95*)
pitch pine **434** (*647*)
pitcheating weevils **282, 296, 315, 318** (*382, 415, 421, 424*)
planar intersect method **142, 159** (*582, 604*)
planing (*1222, 1242, 1243*)
plant collecting (*733*)
plant communities **67, 98** (*273, 649*)
plant control **59, 186, 194, 322, 435, 562, 564** (*252, 476, 497, 526, 654, 782, 790*)
plant cover **28, 29, 52, 470, 474, 476, 483** (*30, 37, 41, 42, 167, 169, 170, 171, 185, 263, 266, 291*)
plant distribution **30, 97, 105, 106, 107, 108, 186, 433, 605, 651, 713** (*164, 165, 255, 461, 497, 634, 642, 735, 736, 738, 739, 757, 860, 861, 896, 897, 900, 902, 908, 1166, 1167, 1215, 1240*)
plant geography **105, 106, 107, 108, 192, 244** (*392, 518, 734, 735, 736, 738, 739*)
plant physiology **207, 586, 593** (*487, 686, 687, 692, 698, 699, 702, 708, 709, 713, 916*)
plant vigor **210, 322** (*264, 477, 526*)
plant water stress **338** (*1, 3, 67*)
plantations **176, 202, 292, 293, 447, 525, 528, 534, 559, 568, 570, 605** (*460, 486, 491, 521, 523, 524, 525, 535, 726, 729, 752, 788, 810, 811, 849, 860, 861, 1031*)
planting **95, 437, 493, 506, 509, 515, 518, 519, 522, 524, 528, 543, 544, 548, 570, 632, 636** (*638, 661, 670, 729, 745, 797, 806, 808, 809, 816, 818, 824, 827, 828, 831, 832, 841, 849, 856, 892, 1065*)
planting stock **528** (*849*)
plastic flow **744** (*1301*)
plus trees (*186*)
plywood **391, 392, 703, 751, 753, 767, 769, 771** (*991, 994, 1001, 1005, 1007, 1072, 1074, 1075, 1076, 1077, 1085, 1086, 1087, 1198, 1212, 1303, 1306, 1334*)
pocket gophers **48** (*210*)
podocarp **508** (*667, 679*)
point sampling **460, 616** (*618, 870, 1022*)
polar substances **354** (*120*)
pole blight **191** (*473, 474*)
poles **678, 779** (*1003, 1072, 1119, 1143, 1156, 1184, 1302*)
pollen **195, 406, 662** (*450, 747, 899*)
pollination **195, 646, 654, 670** (*450, 455, 912, 923, 935*)
pollution **573** (*16, 714*)
pollution control **733** (*562, 1259*)
polymers (*1232*)
polysacharides **734** (*1262*)
pond pine **434** (*647*)
ponderosa pine **2, 16, 46, 47, 194, 245, 247, 249, 297, 303, 322, 340, 369, 379, 399, 416, 418, 419, 448, 489, 515, 516, 521, 554, 613, 634, 637, 660, 779** (*11, 98, 105*
poplar rust (*501*)
poplars **18, 593, 652** (*501, 538, 709, 713, 921, 924*)
population density **43, 48, 50, 224, 242, 303, 304** (*168, 173, 196, 210, 216, 220, 322, 362, 399, 402*)
population dynamics **49, 50, 102, 222, 226, 230, 241, 248, 259, 273, 433, 770** (*196, 199, 234, 241, 243, 332, 333, 343, 347, 352, 359, 375, 383, 642, 644, 1081, 1082*)
potassium **502, 507, 733** (*660, 665, 1259*)
power requirements **687** (*1203*)
precipitation **59, 350, 364, 368, 372, 471, 472** (*31, 33, 45, 60, 72, 74, 76, 88, 95, 97, 121, 135, 145, 149, 194, 236, 252, 264*)
precommercial thinning **122, 441, 547** (*574, 791, 1038, 1225*)
predators **254** (*345, 348*)
predictive models **139, 462** (*590, 628*)
preferences **72, 87** (*283, 294, 310*)
prefreezing **692** (*1164, 1171, 1173, 1176*)
prescribed burning **119, 120, 121, 131, 149, 402, 404, 408, 560, 717** (*86, 228, 245, 251, 546, 547, 564, 568, 614, 633, 749, 753, 755, 792*)
prescribed fire **110, 111, 123, 126, 129, 140, 148** (*544, 548, 549, 556, 557, 560, 561, 562, 563, 566, 567, 569, 571, 572, 573, 575, 607, 616*)
preservatives **699, 704, 705, 722, 724** (*1072, 1159, 1165, 1183, 1184, 1224, 1246, 1283, 1285, 1289*)
presoaking (*1176*)
press drying **702** (*1219*)
press-lam **699** (*1246, 1315*)
pressure treatment **699** (*412, 1241, 1246*)
prestressed beams **744** (*1301*)
price analysis **456, 769** (*1083, 1085, 1106*)
price trends (*1212*)
prices **771** (*1074, 1075, 1076, 1077*)
primary wood industries (*1094*)
private forest lands **390, 446** (*214, 975, 1006, 1042*)
probabilities **611** (*871, 885*)
problem solving **439** (*1026, 1037*)
production **773** (*996, 1074, 1080, 1099, 1140, 1212*)
production costs (*1089, 1139*)
progeny testing **20, 644, 673** (*540, 895, 934, 944*)
propylene oxide **724** (*1285*)
protein production **734** (*1262*)
protein synthesis (*700*)
protocatechuic acid (*475*)
provenance **632, 633, 637, 645, 650** (*194, 891, 892, 901, 914, 915, 916*)
pruning **96, 427, 658** (*746, 764, 765, 932*)
psychological benefits (*301*)
public involvement **82, 86, 86, 88** (*226, 290, 299, 314, 314, 1048*)
public lands (*298, 1006*)
pulp **392, 734** (*1005, 1007, 1156, 1262*)
pulp chips **687, 710, 778** (*1107, 1151, 1203*)
pulp mills **393** (*989, 1000*)
pulp production (*1093*)
pulp viscosity **732** (*1271*)
pulp yield **722** (*1261, 1289*)
pulping **393** (*989, 1266*)
pulpwood **394, 686, 710, 769, 777, 778, 779** (*964, 988, 992, 993, 996, 1000, 1002, 1004, 1074, 1075, 1076, 1080, 1085, 1096, 1102, 110*
pulpwood prices (*993*)
pulpwood production **393** (*989, 997, 998*)
pure culture **179, 188, 198** (*434, 458, 516*)
pyrethrins **299, 300** (*403, 411*)
pyrethroids **298, 301** (*396, 416*)
pyrolysis **155** (*602, 603, 611*)

Q

quaking aspen (*501, 1290*)
quality control **774** (*1116, 1181, 1189*)
quercetin (*488*)
quinones (*1266*)
quit rates **775** (*1118*)

R

rabbitbrush (*166*)
racial variation **643** (*893*)
racking resistance **745** (*1330*)
radial growth **372** (*76*)
radiation **469** (*70, 135, 704*)
radio location telemetry **32, 49** (*179, 205, 212, 219, 221, 241, 242, 243*)
radiography **164, 172, 242, 276, 277, 312** (*320, 322, 334, 373, 409, 436, 844*)
radiological research **432** (*652*)
railroad fires **115** (*558*)
rainfall **1, 4, 7, 184, 332, 346, 468, 482** (*6, 10, 12, 27, 53, 64, 73, 111, 114, 132, 156, 448*)
ranch operations (*1098*)
range condition **52** (*247, 263*)
range improvement **51, 56, 378** (*54, 166, 181, 246, 255, 256, 265*)
range inventory **52** (*263, 266, 983*)
range management **30, 35, 51, 54, 57, 58, 59, 448** (*113, 157, 158, 164, 165, 166, 181, 193, 195, 209, 236, 245, 247, 248, 249, 250, 251, 252, 253, 254, 258, 260, 261, 262, 265, 268, 1050*)
Rankine stresses **712** (*1138*)
raptors (*212*)
rate of return **424, 444** (*778, 1029, 1043*)
raw materials **682** (*1093, 1186*)
ray parenchyma (*505*)
rays **694** (*1220*)

reclamation **473, 474, 475, 476, 477, 478, 479, 481, 482, 483, 484** (*27, 28, 29, 34, 35, 36, 37, 38, 39, 41, 42, 43, 44*)
recovery (*1139, 1179, 1187, 1192, 1199, 1228, 1251*)
recovery ratio **714** (*1178, 1179, 1250*)
recreation activities **64** (*275, 276, 285*)
recreation areas **70** (*278*)
recreation economics **74, 90** (*288, 311, 1049*)
recreation management **64, 68, 69, 70, 75, 76, 78, 79, 80, 81, 84, 89, 90, 711** (*276, 277, 278, 281, 284, 289, 295, 297, 304, 305, 307, 308, 309, 311, 312, 313, 1153*)
recreation research **90** (*65, 284, 311*)
recreation sites **68, 90** (*281, 291, 311*)
recreation structures **709** (*1049, 1110, 1174*)
recreational values **64, 79, 80, 418** (*276, 293, 308, 309, 771*)
recycling **726, 730, 731** (*1268, 1269, 1273, 1274, 1280*)
red alder **183, 330, 366, 558, 609** (*142, 154, 519, 796, 868*)
red elderberry (*234*)
red fir **510** (*823, 1251*)
red maple **20, 131, 212, 213** (*493, 496, 504, 507, 508, 540, 564*)
red oak **402, 564, 596, 694, 709, 739, 751, 773** (*345, 717, 753, 790, 1099, 1174, 1181, 1220, 1238, 1241, 1303, 1308, 1315, 1333*)
red oak borer (*342, 345*)
red pine **22, 257, 292, 293, 311, 491, 492, 524, 526, 576, 741** (*25, 395, 401, 521, 525, 655, 656, 657, 689, 700, 808, 825, 1300*)
red spruce **101, 102, 742** (*240, 643, 644, 645, 1299*)
redwoods **610** (*650, 734, 872*)
refining **726, 729** (*1268, 1270*)
reflectivity **469** (*70*)
reforestation **12, 208, 411, 473, 474, 493, 513, 514, 533, 558** (*17, 34, 41, 462, 463, 661, 767, 796, 804, 810, 836, 847, 848*)
refuse (*1280*)
regeneration **131, 247, 403, 410, 414, 417, 420, 422, 516, 524, 543, 569, 610, 681, 717** (*59, 86, 228, 258, 386, 564, 633, 686, 687, 688, 708, 725, 732, 754, 759, 766, 768, 769, 773, 797, 806, 808, 813, 814, 826, 842, 872, 942, 1124*)
regional planning **454, 471** (*33, 1056*)
regression analysis **226, 267, 271, 319, 350, 380, 609, 611, 617, 684, 688** (*60, 123, 137, 330, 341, 359, 407, 868, 871, 874, 875, 966, 1014, 1096, 1158, 1169, 1227, 1244*)
regulatory agencies **320** (*21, 420*)
relative humidity **193, 230, 459, 746** (*375, 517, 624, 1293, 1298, 1322*)
release **405, 408, 428, 548, 556, 557, 558, 565, 567** (*635, 724, 749, 758, 781, 787, 793, 795, 796, 831*)
remodeling **749** (*1331*)
remote sensing **29, 34, 48, 395** (*158, 159, 160, 167, 168, 169, 170, 171, 173, 210, 883, 1009*)
repairs **690** (*1230*)
repellents **12, 278, 572** (*17, 337, 723*)
reproduction **43, 230, 402, 576, 643** (*216, 375, 689, 690, 753, 893*)
rescue operations (*143*)
research funding (*303*)
Research Natural Areas **675** (*926*)
research programs **38, 65, 84, 97** (*87, 89, 143, 207, 208, 247, 253, 279, 313, 634, 1060, 1310*)
reservoirs **355** (*46*)
residential construction **750, 771** (*1077, 1079, 1095, 1312*)
residue treatments **25, 119, 174, 367, 469** (*18, 23, 70, 116, 445, 449, 547*)
residue utilization **392, 681, 682, 683, 695, 701, 764** (*1005, 1007, 1061, 1062, 1063, 1124, 1130, 1134, 1141, 1168, 1169, 1185, 1186, 1193, 1194, 1199, 1214, 1225, 1226, 1227, 1245, 1248*)
residues **25, 118, 119, 120, 122, 123, 124, 126, 127, 174, 223, 469, 615, 717, 731** (*23, 70, 363, 445, 449, 484, 543, 546, 547, 552, 569, 570, 571, 574, 576, 633, 864, 1191, 1258, 1274*)
resins **628, 629, 735** (*721, 951, 953, 955, 1195, 1196, 1197, 1253, 1282, 1295, 1296, 1297*)
resmethrin **298, 300** (*396, 411*)
resource inventories **34, 449, 625** (*160, 882, 883, 1045*)
resource management **78, 82, 88, 438, 449** (*158, 275, 284, 290, 299, 307, 880, 1025, 1045, 1049*)
respiratory activity (*505*)
revegetation **3, 470, 471, 475, 476, 477, 478, 479, 483** (*7, 28, 29, 30, 32, 33, 35, 36, 37, 38, 39, 42, 162, 237, 757, 1064*)
rhamnose **209** (*489*)
rheological properties **145** (*577, 580, 598*)
rhizosphere **214** (*478*)
ribonuclease **188** (*458*)
ribosomal-RNA (*700*)
ridge regression **617** (*874, 875*)
risks analysis **241** (*332, 333*)
road construction **1, 2, 5, 8, 357, 715** (*9, 10, 11, 63, 84, 106, 141, 149, 151, 1126, 1127, 1136*)
road locations **355** (*46*)
roadway deicing **14** (*440*)
rodent damage **568** (*234, 726*)
rodents **42, 517** (*238, 815*)
roof shingles **755** (*528*)
root biomass **55, 497** (*244, 474, 677*)
root growth **537, 539** (*155, 798, 837*)
root initiation **589, 590** (*695, 696, 697, 710, 712*)
root measurement **55** (*244, 474*)
root morphology **508, 579** (*474, 667, 679, 719*)
root pruning **528** (*849*)
root rots **177, 183, 184, 187, 196, 197, 205, 214** (*448, 478, 482, 483, 484, 490, 492, 510, 512, 513, 519*)
root starch **207, 210** (*477, 487*)
rooting **526, 584, 592, 674** (*183, 694, 825, 936, 1020, 1021*)
rootstocks **669** (*930*)
rootwood (*1193, 1223*)
rosin **735** (*1295*)
rossing **629** (*950, 953*)
rotation grazing (*264*)
rotation length **427** (*764, 765*)
Rothermel model **160** (*612*)
roughage **721** (*1255*)
roundheaded pine beetle **245, 247** (*350, 386*)
roundwood **383, 394, 777** (*963, 987, 988, 997, 1002, 1004, 1080, 1102, 1167*)
ruminant nutrition **53, 721** (*233, 257, 259, 1255*)
runoff **325, 332, 333, 356, 358, 359, 364, 368, 374, 376, 482** (*27, 88, 92, 101, 102, 111, 118, 119, 121, 128, 145, 148, 156*)
rural areas **80** (*308*)
rust **166, 188, 189, 190, 217, 323, 657** (*439, 453, 458, 459, 494, 495, 501, 514, 515, 527, 925*)

S

safety **118** (*570*)
sagebrush **33, 56, 468** (*72, 73, 174, 181, 191, 192, 236, 246, 255*)
salmon **36** (*198, 200, 201*)
salmonberry **557** (*795*)
sample plots **255** (*378*)
sampling **226, 303, 461, 527, 610** (*123, 359, 399, 619, 621, 629, 829, 872, 885, 1012*)
sampling methods **142, 159, 170, 327, 328, 339, 351, 360, 396, 436, 624** (*82, 85, 104, 130, 146, 152, 199, 220, 317, 582, 604, 648, 888, 1012, 1015, 1016, 1022, 1023*)
sand pine **669** (*797, 930*)
sandwich panels **753** (*1306*)
sanitation (*418*)
sap production (*948*)
sapstain fungi **758** (*529*)
sapsucker damage **567** (*724*)
sapwood **692, 693, 757** (*431, 1164, 1172*)
Saratoga spittlebug **257, 261, 262** (*393, 394, 395*)
satisfaction **65, 71, 75, 81, 87** (*279, 282, 295, 297, 310*)
saw-palmetto **499** (*256, 680*)
sawdust **721** (*1063, 1065, 1168, 1169, 1226, 1227, 1255*)
sawflies **235, 283** (*339, 389*)
sawing patterns **685, 696, 698, 773** (*1099, 1161, 1187, 1188, 1189, 1216, 1217, 1231*)
sawlogs **383, 427, 779** (*764, 765, 957, 963, 964, 977, 992, 996, 999, 1002, 1070, 1096, 1119, 1156*)
sawmill equipment (*1161, 1187, 1229*)
sawmill operations **690, 695, 773** (*1099, 1161, 1181, 1189, 1199, 1206, 1217, 1229, 1230, 1248*)

sawmills **392, 696, 698** (*999, 1005, 1007, 1094, 1188, 1216*)
scaling **154, 485** (*605, 867, 1251*)
scanning electron microscopy **190, 718** (*494, 514, 1276, 1277*)
scarab beetles **254** (*348*)
scarlet oak **494** (*672, 1294*)
scenic values **418** (*771*)
scions **669** (*930*)
Scleroderris canker **293, 311** (*401, 525*)
Scolytidae **249, 256, 308** (*353, 356, 422*)
Scotch pine **96, 204, 292, 587, 588, 597, 632** (*509, 521, 523, 706, 707, 720, 746, 892*)
screw withdrawal (*1328, 1329*)
sea breeze **457, 463** (*630, 631*)
seasoning (*1221*)
second-growth stands **714** (*66, 1178, 1179*)
sediment **15, 324** (*12, 15, 114, 150, 156*)
sediment control structures **361, 481, 482** (*27, 43, 83*)
sediment transport **325** (*148*)
sediment yield **8, 325, 343, 344, 360, 381, 482** (*9, 27, 51, 55, 82, 90, 115, 148*)
sedimentation **355, 361, 364, 367** (*46, 83, 84, 116, 121, 151, 197*)
seed collection **27, 553** (*186, 188, 190, 833*)
seed dormancy **193, 551** (*175, 176, 184, 517, 826, 843*)
seed germination **63, 181, 193, 277, 277, 399, 510, 523, 531, 538, 541, 551, 571, 596, 650** (*45, 174, 175, 176, 177, 180, 184, 189, 269, 373, 373, 468, 517, 686, 687, 708, 717, 722, 751, 799, 802, 807, 823, 826, 843, 851, 915*)
seed insects **172, 274, 276, 572** (*320, 334, 336, 723*)
seed orchards **173, 278, 535, 639, 648, 653, 654, 658, 659, 669, 670** (*186, 193, 316, 337, 817, 894, 910, 919, 923, 930, 932, 933, 935, 940*)
seed physiology **27, 531, 541, 596** (*175, 177, 180, 188, 717, 802, 851*)
seed processing **511** (*838*)
seed production **35, 399, 406** (*157, 186, 193, 747, 751*)
seed scarification (*175*)
seed source **20, 514, 529, 536, 632, 633, 635, 637, 638** (*540, 732, 820, 848, 850, 891, 892, 903, 906, 907, 914, 917, 942*)
seed storage **181, 193, 523, 531, 538, 541, 596** (*189, 190, 468, 517, 717, 799, 802, 807, 851*)
seed testing **27, 542, 550, 553** (*176, 188, 803, 833, 845*)
seed yield **276, 409, 653, 667, 668, 670** (*334, 750, 919, 928, 929, 935*)
seed zones **635** (*906, 907*)
seedbed preparation **470** (*30, 548*)
seedbugs **277, 654** (*373, 923*)
seeding **2, 85, 476, 517, 538** (*11, 35, 42, 287, 291, 799, 815*)
seeding equipment **530, 676** (*812, 1131, 1147*)
seedling diseases **196, 197** (*490, 491, 492*)
seedling establishment **377, 402, 473, 475, 476** (*28, 34, 42, 45, 144, 182, 291, 753*)
seedling growth **473, 507, 513, 525, 587, 588** (*34, 665, 706, 707, 811, 847*)
seedling storage **515** (*809, 832*)
seedling survival **2, 4, 63, 282, 296, 311, 348, 401, 430, 473, 474, 478, 513, 518, 539, 540, 598** (*6, 11, 29, 34, 41, 45, 59, 108, 162, 176, 194, 195, 269, 291, 382, 401, 415, 653, 756, 798, 800, 827, 847, 862*)
seedlings **19, 100, 215, 315, 316, 412, 509, 516, 520, 522, 610** (*424, 425, 479, 537, 731, 775, 781, 805, 813, 814, 824, 839, 841, 842, 872, 1066*)
seeds **553, 581** (*685, 686, 687, 833, 844, 844*)
seepage **712** (*1137, 1138*)
seismic surveys (*145, 151*)
selection **421, 424, 627, 635, 644, 645, 664, 665, 673** (*770, 778, 805, 856, 895, 901, 906, 907, 917, 927, 944, 945, 949, 1036*)
selection cutting **374, 422, 444** (*101, 773, 1043*)
self pollination **667, 668** (*928, 929*)
selfing **660, 670** (*935, 943*)
semantic differential **61** (*271, 293*)
sensitivity analysis **380, 461** (*137, 619, 622*)
sensitometry **164** (*436*)
sensory impairment (*249*)
sewage disposal **22, 23, 24, 734** (*24, 25, 26, 1262*)
sewage effluent **22, 24** (*25, 26*)
sexual reproduction **648, 651** (*896, 897, 900, 902, 908, 910*)
shade trees **91, 167, 168** (*443, 444, 741*)
shakes **165** (*441, 1221*)
shaping lathe headrig (*1205, 1206*)
sharp-tailed grouse (*211*)
shavings (*1063*)
shear strength **703, 742** (*1198, 1299, 1334*)
shear stress **743** (*1314*)
shearing **96, 706** (*746, 1122*)
sheathing **714** (*1178, 1191, 1332*)
sheep (*249*)
sheet density **726** (*1268*)
sheet mold **727** (*1291*)
shelterbelt entomology **251, 252, 310** (*384, 385, 419*)
shelterbelts **93, 94, 95** (*740, 743, 744, 745*)
shelterwood **407, 412, 420** (*748, 768, 775*)
Shigometer **165** (*441, 442*)
shoot growth **595** (*715*)
shoot/root ratio **524, 537, 586** (*702, 808, 837*)
short rotation **532, 552** (*801, 834*)
short-hair sedge **28** (*185*)
shortgrass prairie **55** (*155, 244*)
shortleaf pine **275, 275, 276, 544, 547, 565, 605** (*228, 334, 335, 335, 791, 793, 818, 860, 861, 1142, 1278*)
shredder **730** (*1273*)
shrinkage **678, 679, 680, 693, 702, 724, 725** (*1143, 1171, 1172, 1176, 1190, 1200, 1201, 1202, 1204, 1219, 1256, 128*
shrublands (*181, 247*)
shrubs **186** (*159, 162, 182, 193, 235, 255, 256, 497*)
Shumard oak **542** (*803*)
Siberian elm **251** (*384*)
sidecasting (*1126*)
silica content **701** (*1214*)
sill sampler **360** (*82*)
siltation **437** (*638*)
silvicides **558** (*796*)
silvicultural control **266, 318** (*328, 329, 421*)
silvicultural conversion **51, 344, 345, 349, 380, 440, 544** (*61, 90, 94, 137, 265, 818, 1028*)
silvicultural methods **309, 411, 415, 416, 417, 419, 422, 425, 429, 569** (*400, 636, 725, 760, 763, 767, 769, 773, 774, 779, 856*)
silvicultural systems **444, 580** (*705, 1043*)
silvicultural treatments **24, 187, 380, 390, 407, 412, 440** (*26, 137, 510, 748, 775, 975, 1028, 1033*)
silviculture **119, 414, 415, 417, 418, 424, 488, 555, 556, 717** (*547, 633, 674, 759, 760, 769, 771, 778, 783, 786, 787, 794, 913, 917*)
simulation analysis **373, 374, 461, 621, 685** (*100, 101, 619, 622, 641, 878, 1126, 1128, 1133, 1135, 1136, 1141, 1154, 1231*)
site classification **386, 401, 479, 559** (*39, 236, 756, 788, 976, 1011*)
site deterioration **68, 75, 85** (*281, 284, 287, 289, 295*)
site factors **414, 415, 425, 494, 515** (*312, 672, 759, 760, 779, 809*)
site index **323, 397, 414, 491, 494, 500, 601, 605, 608** (*527, 655, 672, 682, 759, 853, 860, 861, 869, 979, 1013, 1019, 1024*)
site index curves **493, 608, 609, 636** (*661, 816, 868, 869, 1011*)
site preparation **111, 428, 499, 504, 505, 506, 530, 540, 543, 557, 558, 560, 681** (*548, 557, 635, 669, 670, 671, 680, 792, 795, 796, 800, 806, 812, 1124*)
site quality **3, 694** (*7, 704, 1011, 1013, 1036, 1220*)
site rehabilitation **85, 471** (*32, 33, 287*)
Sitka spruce (*1018*)
Sitka spruce weevil **225** (*361*)
size class **97** (*634*)
skewness (*621, 629*)
skid trails **689** (*12, 1155*)
skidding (*1129, 1136*)
skiing **75** (*295*)
skyline logging (*139, 1128, 1129, 1134, 1146, 1149*)
slash **62, 117, 119, 120, 122, 124, 142, 174, 329, 330, 367, 681, 717** (*116, 153,*

154, 272, 445, 449, 451, 546, 547, 552, 553, 574, 576, 582, 633, 1124)
slash disposal **26, 121, 122, 123, 148** (*161, 568, 569, 574, 607*)
slash pine **111, 166, 173, 277, 278, 323, 447, 504, 505, 506, 540, 545, 547, 552, 629, 643, 656, 670, 673, 688** (*260, 316, 337, 373, 439, 527, 557, 669, 670, 671, 791, 800, 821, 834, 893, 913, 917, 922, 935, 944, 953, 1031, 1142, 1144, 1145, 1158, 1168, 1193, 1194*)
slope **352, 361, 379** (*83, 98, 133*)
slope stability **6, 7, 472, 484, 712** (*31, 44, 131, 132, 1137, 1138*)
sludge **24** (*26*)
smoke **110, 111, 120, 141, 148, 460, 752** (*546, 557, 560, 561, 563, 566, 573, 575, 581, 607,*
smoke management **111, 120, 149** (*544, 546, 557, 560, 563, 614*)
smooth brome (*177*)
snails (*201*)
snow accumulation **342** (*78, 243*)
snow chemistry **335, 356** (*92, 93, 103, 104*)
snow damage **208** (*462, 463*)
snow density **341, 371, 372** (*71, 76, 126*)
snow fences **375** (*134, 138*)
snow loads **745** (*1330*)
snow management **336** (*81*)
snow research (*117*)
snow survey **333, 379** (*98, 102*)
snowmelt **333, 334, 335, 342, 356, 373, 376, 622** (*75, 78, 92, 100, 102, 103, 125, 128, 881*)
snowpack **333, 334, 335, 356, 372, 379** (*75, 76, 92, 93, 98, 102, 103, 104, 125*)
sodium carbonate (*1278*)
sodium hydroxide **726, 733** (*1259, 1268*)
sodium N-methyldithiocarbamate **722** (*1289*)
soft maple (*1207*)
soft rot fungi **758** (*529*)
softwoods **726, 756, 759, 761** (*429, 433, 531, 1106, 1215, 1222, 1267, 1268, 1279, 1296*)
soil amendment **764** (*35, 1062, 1065, 1066*)
soil analysis **490** (*676*)
soil atmosphere **498** (*666*)
soil bulk density **516** (*813, 814*)
soil chemical properties **43, 401, 477, 492** (*38, 216, 657, 756*)
soil chemistry (*18, 449*)
soil compaction **57, 68, 367** (*18, 113, 116, 250, 280, 281, 289*)
soil creep **6, 7** (*131, 132*)
soil disturbance **23, 26** (*24, 161*)
soil moisture **25, 339, 340, 518** (*1, 23, 45, 52, 58, 85, 105, 156, 704, 827*)
soil organisms **11, 25, 183, 366** (*13, 23, 142, 449, 519*)
soil physical properties **15, 401, 477, 492, 712** (*15, 38, 57, 113, 151, 449, 657, 704, 756, 1138*)
soil properties **3, 22, 712** (*7, 25, 194, 1138*)
soil stability **6, 367, 483** (*37, 116, 131, 182, 255, 1137*)
soil temperature **25, 334, 518** (*23, 125, 483, 827*)
soil wettability **354** (*56, 57, 114, 120*)
soils **332, 347, 492, 526** (*20, 56, 57, 110, 111, 656, 657, 825*)
solar radiation **91, 336, 352, 519** (*81, 133, 741, 828*)
solvents (*1236, 1265*)
songbirds **37, 39, 40, 42, 44** (*204, 206, 213, 238, 239*)
sound insulation **750** (*1312*)
southern pecan **211** (*503*)
southern pine beetle **280, 284, 285, 286, 287, 319** (*323, 331, 346, 365, 379, 407*)
southern pines **172, 274, 275, 386, 445, 455, 456, 539, 546, 552, 654, 679, 718, 721, 726, 739, 740** (*186, 237, 261, 320, 335, 336, 567, 688, 798, 819, 834, 923, 976, 994, 1030, 1058, 1083, 1106, 1184, 1195, 1196, 1197, 1200, 1201, 1202, 1206, 1255, 1268, 1276, 1308, 1313, 1316, 1317, 1318, 1319, 1*)
southwestern pine tip moth **248** (*347*)
spacing **559, 598, 603** (*788, 857, 862*)
spark arresters **115** (*558*)
spawning beds (*198*)
speciality products (*1211*)
species description **182, 265, 286** (*172, 358, 379, 454*)
species diversity **103, 183, 247** (*386, 519, 646*)
species range **101** (*237, 640, 643, 645, 730, 732, 734*)
species trials **514, 598** (*848, 862*)
specific gravity **427, 510, 684, 691, 700, 707, 740, 742** (*764, 765, 823, 1163, 1182, 1193, 1196, 1235, 1244, 1299, 1313, 1332*)
spectral signature **34** (*160*)
spectrometry (*1286*)
sporulation **189** (*459*)
spot seeding **517, 549** (*815, 830*)
spray equipment **295** (*408*)
spray schedule **291** (*522*)
spring cankerworm **251, 252, 300, 301** (*384, 385, 411, 416*)
sprouts **131, 405, 610** (*564, 758, 872*)
spruce **100, 225, 305, 721** (*361, 405, 731, 1255*)
spruce beetle **255, 294, 305** (*378, 405, 417*)
spruce budworm **229** (*377*)
spruce-fir **374, 415, 433, 434, 621, 622** (*101, 642, 647, 760, 785, 878, 881*)
squirrels **32, 47, 201** (*179, 224, 465*)
squirreltail **56** (*246*)
stabilizers (*1279*)
staining techniques (*180, 1263*)
stand composition **266, 319, 434, 436** (*237, 328, 329, 407, 647, 648, 1036*)
stand density **319, 412, 601, 604** (*407, 775, 853, 858, 1013*)
stand development **4, 411, 423, 441** (*6, 767, 776, 1038*)
stand growth **565, 580** (*705, 793*)
stand structure **605** (*860, 861*)
stand volume (*1022, 1029*)
stand yield tables **397, 621** (*878, 1011, 1019*)
starch contents **207, 210** (*477, 487*)
state of the art **417, 419, 717** (*633, 769, 774*)
statistical analyses **617** (*627, 874, 875*)
statistical techniques **465** (*620, 621, 629*)
statistics (*620, 621, 629, 648, 1244, 1299, 1313, 1332*)
snow fences **375** (*134, 138*)
snow loads **745** (*1330*)
snow management **336** (*81*)
snow research (*117*)
snow survey **333, 379** (*98, 102*)
snowmelt **333, 334, 335, 342, 356, 373, 376, 622** (*75, 78, 92, 100, 102, 103, 125, 128, 881*)
snowpack **333, 334, 335, 356, 372, 379** (*75, 76, 92, 93, 98, 102, 103, 104, 125*)
sodium carbonate (*1278*)
sodium hydroxide **726, 733** (*1259, 1268*)
sodium N-methyldithiocarbamate **722** (*1289*)
soft maple (*1207*)
soft rot fungi **758** (*529*)
softwoods **726, 756, 759, 761** (*429, 433, 531, 1106, 1215, 1222, 1267, 1268, 1279, 1296*)
soil amendment **764** (*35, 1062, 1065, 1066*)
soil analysis **490** (*676*)
soil atmosphere **498** (*666*)
soil bulk density **516** (*81*
steaming (*1121, 1238*)
steel framing (*1079*)
stem diseases **163, 196, 197** (*437, 490, 492*)
stem measurements **500, 585, 606, 608, 613** (*682, 701, 866, 869, 876, 1014, 1014, 1302*)
stems **351** (*130, 512*)
stemwood **719** (*1275*)
stereoradiography **550** (*845*)
sterile male technique **273** (*383*)
stiffness **700, 701, 728, 736, 740, 747, 748** (*1182, 1214, 1287, 1288, 1290, 1313, 1318, 1322, 1324, 1325*)
stochastic process (*650*)
stocking **400, 559, 604, 610** (*777, 788, 858, 872*)
stocking density **307, 397** (*423, 1019*)
stocking guides **423, 448** (*248, 251, 776, 1050*)
stomata **338** (*67, 68*)
storage conditions (*1109*)
stored foods **581** (*685*)
storm hydrographs (*145*)
stratification **551, 727** (*843, 1291*)
stream channels **329** (*153*)
stream discharge **361, 364** (*83, 121*)
stream habitat (*198, 199*)
stream hydraulics **360** (*82*)
stream temperature **326, 368** (*88, 147*)
streamflow **324, 325, 326, 327, 331, 332, 333, 337, 338, 343, 344, 345, 347, 350,**

355, 356, 363, 364, 376, 381 (*46, 47, 51, 55, 60, 63, 66, 67, 69, 84, 90, 91, 92, 93, 94, 96, 99, 102, 110, 111, 121, 128, 129, 146, 147, 148, 150, 197*)
streams **10, 330** (*22, 151, 154*)
strength properties **726, 740** (*1193, 1194, 1234, 1247, 1268, 1278, 1279, 1282, 1290, 1307, 1309, 1310, 1313, 1316, 1317, 1318, 1319, 1320, 1322, 1323, 1326*)
stress skin panels **743** (*1314*)
stresses **210** (*477, 1317, 1318*)
strip cutting **337** (*91*)
striped maple **102** (*644*)
structural stability **738** (*1305*)
studs **680, 750** (*1201, 1204, 1312*)
stumpage **441, 455** (*1038, 1058, 1074, 1075, 1076, 1106, 1139*)
subalpine fir **255, 621** (*378, 878*)
subalpine forests **415, 622** (*760, 881*)
submerged wood **741** (*1300*)
succession **56, 66, 97, 102, 165, 192, 247, 255, 434, 499** (*140, 246, 274, 378, 386, 441, 518, 634, 644, 647, 680*)
succinylcholine chloride (*227*)
sucker sprouts (*637*)
sucrose **195, 207** (*450, 487*)
sugar maple **101, 102, 131, 199, 207, 210, 213, 531, 570** (*466, 477, 487, 508, 512, 564, 643, 644, 645, 729, 851, 948, 1120, 1121, 1241*)
sugars **195, 209** (*450, 489, 1286*)
sulfate determination (*109*)
sulfur dioxide **16, 17, 19, 21** (*534, 535, 536, 537, 662*)
supplemental feeding **37, 53** (*206, 248, 257, 258*)
supply and demand (*1140, 1180*)
surface area **351** (*122, 123, 130, 1014*)
surface erosion **2** (*11*)
surface mining (*32*)
surface quality (*1242, 1243*)
surface tension (*1196*)
surveys **73, 79** (*302, 309, 956*)
survival **49, 177, 504, 544, 637** (*241, 482, 650, 669, 810, 818, 914*)
survival education (*300, 301*)
susceptibility **217, 306** (*414, 418, 453*)
sustained yield (*772*)
swamps (*49*)
sweet fern **261, 262** (*393, 394*)
sweetgum **434, 437, 502** (*638, 647, 660, 1238, 1241*)
swelling **707, 724** (*1233, 1235, 1236, 1285, 1293*)
sycamore **437, 532, 534, 585, 603** (*638, 701, 752, 801, 857, 1281*)
symbiosis **163, 377** (*144, 437*)
symptoms **16, 167, 194, 204, 292** (*444, 476, 491, 509, 521, 536*)
synoptic catalog **235** (*389*)
syringaldazine **221** (*457, 1263*)
syringic acid (*475*)
syrup marketing **776** (*1108*)
systems analysis **623, 624** (*641, 888, 889*)

T

tall oil **722, 735** (*1289, 1295, 1296*)
tamarack **403, 741** (*754, 1300*)
tannins (*488*)
taproots **686** (*1132, 1142, 1144, 1145, 1193, 1199, 1206*)
tax rates (*1041*)
taxonomy **30, 31, 106, 107, 179, 182, 219, 220, 227, 228, 231, 235, 236, 256, 265, 286, 651, 756** (*164, 165, 166, 172, 178, 191, 353, 358, 360, 379, 388, 389, 390, 391, 434, 451, 452, 454, 470, 471, 472, 531, 736, 738, 896, 897, 900, 902, 908*)
TCDD **10** (*22*)
technology transfer (*117, 1060*)
telemetry **464** (*625*)
temperature **91, 156, 157, 174, 193, 250, 257, 304, 334, 341, 457, 468, 469, 538, 678, 679, 702, 723, 724, 728, 729, 737** (*2, 70, 71, 73, 77, 125, 135, 174, 194, 197, 342, 355, 395, 402, 445, 517, 608, 613, 617, 631, 704, 741, 799, 1143, 1202, 1219, 1260, 1270, 1284, 1285, 1288*)
temperature tolerance (*483*)
tensile strength **371, 725** (*126, 1256, 1257, 1267, 1309, 1329*)
tension wood (*1221*)
termite contracts **320** (*420*)
termites **757, 759, 760, 762** (*428, 429, 430, 431, 1095, 1239*)
terpene **649, 655** (*909, 920*)
territorial homing (*221*)
test furnace (*1304*)
Texas leaf-cutting ant **289** (*369*)
thermal convection model **156** (*613*)
thermal efficiency **680** (*1204*)
thermocouple psychrometers (*2, 4, 5, 52*)
thin plates **706** (*1122*)
thinning **307, 418, 427, 441, 447, 486, 487, 547, 554, 559, 580, 600, 601, 604, 614, 708** (*423, 663, 664, 675, 705, 761, 764, 765, 771, 788, 791, 853, 855, 858, 859, 863, 1031, 1038, 1175*)
timber appraisal **616** (*870, 1029, 1139*)
timber contracts (*1052, 1111*)
timber demand **766, 769** (*1078, 1084, 1085*)
timber harvest **6, 7, 118, 373, 447, 454, 622, 681, 686, 688, 710** (*12, 96, 99, 100, 131, 132, 242, 293, 570, 881, 990, 1006, 1008, 1031, 1035, 1054, 1056, 1124, 1125, 1128, 1*
timber industries (*1002*)
timber management **415, 418, 429, 440, 445, 448, 450, 451, 621, 711, 715, 766** (*214, 240, 251, 293, 636, 734, 760, 771, 878, 1028, 1030, 1035, 1047, 1050, 1051, 1084, 1127, 1153, 1156*)
timber marking **444** (*1043*)
timber production **381, 390, 443, 450, 602, 711** (*51, 854, 975, 979, 990, 996, 1027, 1039, 1046, 1051, 1054, 1153, 1157, 1167*)
timber receipts (*987*)
timber resources **382, 383, 385, 387, 388, 389, 390, 419** (*774, 957, 958, 959, 960, 962, 963, 964, 965, 967, 968, 969, 970, 971, 972, 974, 975, 978, 980, 982, 983, 984, 985, 986*)
timber stand improvement **111, 440, 561, 563, 565** (*557, 783, 784, 785, 789, 793, 794, 1027, 1028*)
timber supply **382, 383, 385, 387, 389, 390, 766** (*957, 958, 959, 960, 962, 963, 964, 965, 967, 968, 969, 970, 972, 973, 974, 975, 978, 980, 982, 984, 985, 1027, 1078, 1084, 1140*)
timber utilization **116, 386, 390, 683, 685** (*541, 975, 976, 1004, 1008, 1101, 1125, 1170, 1180, 1185, 1205, 1206, 1231*)
timber volume **383, 386, 390** (*958, 962, 963, 964, 967, 972, 973, 975, 976, 977, 978, 984, 1029*)
time area counts (*242*)
timothy (*163*)
tissue culture **188** (*458, 835*)
top-dressing **470** (*30*)
toxicants **16, 18, 19, 20** (*536, 537, 538, 539, 540*)
toxicity **10, 11, 22, 36, 301, 302, 316, 724, 734** (*13, 14, 20, 22, 25, 200, 416, 425, 426, 1183, 1262, 1285*)
tracheids **597, 718** (*720, 1276*)
tracking systems (*205, 219, 242*)
trade **769** (*1085, 1167*)
training aids (*530*)
trampling **57** (*250*)
transpiration **91, 338, 340, 348** (*66, 67, 68, 77, 105, 108, 741*)
transportation (*1123*)
trapping **50, 169, 361, 431, 431** (*83, 196, 221, 315, 632, 632*)
tree breeding **635, 639, 640, 645, 647, 651, 652, 656, 661, 662, 663, 664** (*894, 896, 897, 899, 900, 901, 902, 905, 906, 907, 908, 911, 921, 922, 924, 937, 945, 946*)
tree improvement **521, 626, 627, 635, 638, 639, 641, 642, 643, 644, 645, 646, 647, 648, 651, 653, 656, 657, 658, 659, 660, 663, 664, 665, 671, 673, 674** (*840, 890, 893, 894, 895, 896, 897, 900, 901, 902, 903, 905, 906, 907, 908, 910, 912, 918, 919, 922, 925, 927, 931, 932, 933, 934, 934, 936, 939, 940, 943, 944, 945, 946, 947, 949, 1033*)
tree injury **199** (*466*)
tree physiology **594** (*716*)
tree quality **131, 567** (*564, 724*)
tree volume **323, 612** (*527, 873*)
tree weight (*1170*)
tree-length logs (*1096, 1154*)
trembling aspen **404** (*755*)
trend analysis **78, 374** (*101, 307, 1139*)
trichlorfon **302** (*426*)
tropical forests **106, 288, 493, 650** (*371, 661, 736, 915, 1166, 1167, 1180, 1247*)
tropical woods **760** (*428*)
trout (*87, 198*)
tubers (*183*)
turbidity **326** (*147*)
turpentine **629, 722** (*953, 1289*)
tyloses **631** (*954*)
type conversion **58, 331, 386, 445** (*89, 129, 254, 976, 1030, 1032*)
type distribution (*981*)

U

ultramafic soils **634** (*898*)

ultrastructure **551** (*843*)
ultraviolet light **705** (*1159*)
understory vegetation **26, 39, 104, 366** (*142, 161, 213, 228, 237, 251, 639, 757*)
uneven-aged stands **421, 422, 424** (*770, 773, 778*)
Uniola species (*195*)
urban forestry **20, 38, 79, 80, 91, 92, 206** (*207, 208, 294, 308, 309, 464, 540, 741, 742*)
urban rehabilitation (*1103, 1104*)
urban wildlife **37, 41, 42** (*206, 207, 223, 238*)
urea **177** (*482*)
urea formaldehyde (*1195*)
user permits **69, 70, 75** (*277, 278, 295, 298*)
user surveys **65, 70, 72, 75, 76, 77, 87, 89** (*278, 279, 283, 295, 304, 305, 306, 310*)
user's manual **137** (*555*)
utility poles **704** (*1165*)
utilization **117, 577** (*552, 553, 691*)
utilization standards **127** (*543*)

V

vanillic acid (*475*)
vapor barriers **738, 746** (*1224, 1298, 1305*)
varnishleaf ceanothus **556** (*787*)
vascular tissue (*505*)
vegetation **108, 369** (*112, 737, 739*)
vegetation barriers **92** (*280, 742*)
vegetation change (*253*)
vegetation classification **29, 34** (*160, 167*)
vegetation treatments **343, 380, 552** (*55, 115, 137, 834*)
vegetation types **28, 34, 56, 67, 107, 471** (*33, 160, 185, 245, 246, 268, 273, 738*)
vegetative propagation **35, 534, 535, 586, 589, 591, 593, 636, 666, 674** (*157, 187, 702, 709, 711, 712, 713, 752, 816, 817, 936, 938*)
veneer **392, 678, 688, 699, 702, 769** (*992, 994, 1004, 1005, 1007, 1085, 1143, 1156, 1158, 1201, 1218, 1219, 1246, 1251*)
veneer containers (*1001*)
veneer grading (*1250, 1251*)
veneer logs **391, 779** (*991, 995, 996, 1001, 1002, 1096, 1119*)
veneer mills **391** (*991, 995, 1001*)
veneer production (*995*)
veneer recovery **714** (*1178*)
ventilation **746** (*1298*)
vermiculite **526** (*825*)
vertebrates **98** (*649*)
vessel plugs (*505*)
vessels **694** (*1220*)
viability **193, 399, 510, 514, 523, 531, 550** (*176, 180, 189, 190, 517, 751, 807, 823, 845, 848, 851*)
vine maple **557, 558** (*795, 796*)
Virginia pine **434, 479, 544, 547, 549** (*39, 240, 647, 791, 818, 830*)
viruses **211, 228, 269** (*372, 391, 503*)
viscosity (*1272*)
visibility **141, 459** (*556, 581, 624, 627*)
visitor information **69, 84** (*277, 313*)
visual analysis **34, 60, 61, 210, 425** (*160, 240, 270, 271, 293, 477, 779*)
visual grading (*1307, 1309*)
volcanic soils **401** (*756*)
volume measurement **427, 485, 599, 606, 612, 688, 777** (*764, 765, 852, 866, 867, 873, 1102, 1158, 1168*)
volume tables **599, 605, 613, 708** (*852, 860, 861, 876, 1175, 1207, 1208, 1209, 1210*)

W

wages (*1059*)
walking trails **39** (*213*)
wall framing **753** (*1079, 1306*)
walnut **577, 666** (*691, 938*)
warp **679** (*1200, 1201, 1202*)
waste disposal **730** (*65, 1273*)
waste treatment (*62*)
wastepaper **730, 731** (*1273, 1274, 1280*)
wastewater **22, 24** (*25, 26*)
water **425, 758** (*529, 779*)
water chemistry **326, 364** (*109, 121, 147, 197*)
water cycling (*856*)
water layering (*699*)
water management **333** (*62, 102*)
water oak **502, 541, 542, 551** (*660, 802, 803, 843*)
water pollution **23, 327, 328, 734** (*24, 146, 152, 1123, 1262*)
water potential **340** (*1, 2, 3, 4, 5, 52, 68, 105, 177*)
water quality **12, 23, 24, 324, 326, 327, 330, 337, 343, 347, 349, 357, 367, 381, 481** (*17, 24, 26, 43, 51, 55, 61, 62, 63, 79, 91, 110, 116, 141, 146, 147, 149, 150, 154*)
water resources **332** (*111*)
water table **328, 362, 363** (*47, 48, 49, 50, 152*)
water tupelo (*1241*)
water use **333** (*58, 102, 203*)
water yield **326, 331, 334, 337, 338, 342, 343, 344, 345, 347, 349, 363, 367, 368, 369, 373, 374, 381, 622** (*47, 51, 55, 58, 61, 62, 63, 67, 68, 75, 78, 88, 89, 90, 91, 94, 99, 100, 101, 110, 112, 115, 116, 125, 129, 147, 881, 1046*)
waterlogging **505, 506** (*670, 671*)
watershed management **331, 332, 337, 342, 343, 344, 345, 349, 355, 358, 359, 364, 365, 367, 368, 373, 375, 380, 381, 514** (*46, 51, 55, 61, 75, 78, 87, 88, 89, 90, 91, 94, 99, 100, 111, 114, 115, 116, 118, 119, 121, 124, 129, 134, 137, 240, 848, 1046*)
watersheds **8, 324, 356** (*9, 92, 93, 145, 150*)
weather **149, 370** (*107, 143, 243, 614*)
weather data **463** (*53, 72, 630*)
weather forecasting **459** (*53, 622, 624, 627*)
weather modification **466, 467** (*74, 601, 606*)
weathering **347** (*110, 151*)
web tension **725, 729** (*1256, 1270*)
weeding **548** (*831*)
Weibull distribution **371** (*122, 126*)
weight scaling **777** (*1096, 1102*)
western hemlock **97, 330** (*154, 634, 1018*)
western hemlock looper **301** (*416*)
western larch **232, 233, 515** (*374, 376, 809, 832*)
western pine beetle **170, 238, 297** (*317, 349, 398*)
western redcedar (*1184, 1302*)
western spruce budworm **295** (*408*)
western thimbleberry **557** (*795*)
western white pine **191, 611** (*473, 871*)
wet pressing **729** (*1270*)
wetlands **362** (*49, 50*)
wetwood (*1223, 1249, 1252*)
white ash **213** (*508*)
white birch **131** (*564*)
white fir **175, 195, 222, 239, 510** (*340, 352, 446, 450, 823, 1228, 1238, 1251*)
white fir needle miner **244** (*392*)
white grubs **311** (*401*)
white oak **494, 542** (*672, 803, 1241*)
white pine **208, 351, 517, 530, 611, 741** (*122, 130, 240, 462, 463, 812, 815, 871, 1300*)
white pine blister rust **188, 189, 190** (*458, 459, 494, 495, 514, 515*)
white pine weevil **225** (*361*)
white rots **174, 220, 221, 754** (*445, 451, 457, 469, 470, 532, 533*)
white spruce **599, 742** (*656, 852, 1299*)
whole tree harvesting (*1121, 1134, 1141, 1142, 1144, 1145, 1154, 1199, 1206*)
whole tree utilization **684** (*1061, 1148, 1244*)
wild cherry **301** (*416*)
wild turkey **45** (*217, 218*)
wilderness areas **64, 66, 67, 68, 69, 71, 80, 128, 153** (*65, 273, 274, 276, 277, 280, 281, 282, 308, 312, 585, 593*)
wilderness management **67, 72** (*273, 283, 298*)
wilderness recreation **65, 69, 70, 71, 72, 89** (*275, 277, 278, 279, 282, 283, 298, 300, 301, 303, 305*)
wildfire **115, 132, 138, 140, 141, 434** (*56, 57, 558, 561, 581, 587, 594, 616, 647*)
wildflowers **103** (*646*)
wildland fires **157** (*608, 623*)
wildlife **425** (*201, 772, 779*)
wildlife behavior patterns **45** (*217, 218*)
wildlife habitat **32, 38, 39, 40, 41, 42, 44, 46, 66, 104, 499, 681** (*179, 204, 207, 208, 209, 213, 222, 223, 225, 232, 238, 239, 243, 251, 274, 639, 680, 1124*)
wildlife habitat management **451** (*212, 548, 1047*)
wildlife management **32, 37, 38, 41, 43, 44, 46, 47, 49, 79, 81** (*179, 197, 202, 203, 204, 205, 206, 207, 208, 214, 215, 216, 219, 221, 222, 223, 224, 225, 226,*

227, 230, 231, 233, 234, 235, 236, 240, 241, 242, 297, 309, 772)
wildlife research (*303*)
willow **586** (*702*)
willow oak **502, 541** (*481, 660, 802*)
wilting point (*1, 3*)
wind **156, 462** (*613, 617, 623, 628*)
wind loads **745** (*1330*)
wind models **460** (*618*)
wind pollination (*455*)
wind velocity **457, 459, 460** (*77, 617, 618, 624, 631*)
winter feeding (*243*)
winter injury **200** (*194, 485, 539*)
winterfat (*189*)
wiregrass **499** (*680*)
wolves **49** (*231, 241*)
wood borers **171, 290, 763** (*318, 319, 381, 432, 1239*)
wood catabolism **757** (*431*)
wood chips (*993*)
wood consumption (*1093*)
wood decay **175, 221, 701, 754** (*442, 446, 457, 467, 469, 532, 533, 1095, 1214, 1224, 1239*)
wood decay fungi **704, 758** (*529, 1165, 1184, 1224, 1263*)
wood finishes **705** (*1159*)
wood moisture (*1233, 1236*)
wood products **165, 392, 450, 758, 774** (*441, 529, 530, 772, 1007, 1051, 1090, 1091, 1093, 1100, 1110, 1114, 1116, 1117, 1166, 1211*)
wood products industries **775** (*1118*)
wood properties **445, 642, 713** (*890, 1030, 1166, 1221, 1240*)
wood residues **117, 223, 393, 394, 682, 688, 695, 721, 731, 764** (*363, 552, 553, 988, 989, 992, 993, 996, 997, 998, 999, 1001, 1002, 1062, 1063, 1064, 1065, 1066, 1070, 1071, 1101, 1134, 1158, 1168, 1169, 1186, 1226, 1227, 1245, 1248, 1255, 1274*)
wood siding **738** (*1305*)
wood use **392, 713, 767** (*1005, 1007, 1086, 1089, 1097, 1112, 1166, 1211, 1215, 1240*)
woodpeckers **44** (*204*)
woody plants **27** (*181, 188*)
worms (*201*)
wound invaders **213** (*508*)
wounds **165, 213** (*441, 493, 496, 505, 506, 507, 508*)

X

x-pinene **240** (*327*)
x-rays **164, 550** (*436, 844, 845*)
xylem **239, 597, 631** (*68, 340, 720, 954*)
xylose (*1281, 1286*)

Y

yarders **689** (*1155*)
yeast **755** (*528*)
yellow birch **101, 102, 131, 213, 523, 567** (*508, 564, 643, 644, 645, 692, 724, 807, 1241*)
yellow pine **704** (*1165*)
yellow-poplar **434, 437, 495, 502, 525, 537, 544, 561, 580, 600, 601, 614, 691, 708** (*638, 647, 658, 660, 705, 781, 784, 811, 818, 837, 853, 855, 859, 863, 1113, 1163, 1169, 1175, 1236, 1333*)
yellows chlorosis **196** (*490*)
yield **381, 414, 419, 427, 554, 604, 605, 613** (*51, 759, 761, 764, 765, 772, 774, 858, 860, 861, 876, 979, 1013, 1156, 1187, 1189, 1209, 1225*)
yield tables **608** (*869, 1169, 1226, 1250*)
youth camps (*300*)

Z

ziram **293** (*525*)
zoology **98** (*649*)

2

2,4-D **33, 36** (*192, 200, 201, 412*)
2,4,5-T **10** (*22, 201*)

3

3P sampling **396, 616** (*870, 1022, 1023*)

4

4-alkoxyl group oxygenation (*533*)

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